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SHUTTLE SORTIE SIMULATION USING A LEAR JET AIRCRAFT – MISSION NO. 1 (ASSESS PROGRAM)

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SUMMARY

The first Shuttle Sortie simulation mission of the ASSESS Program was conducted by the Airborne Science Office (ASO) at the Ames Research Center using a Lear Jet aircraft in conjunction with a ground-based complex to serve as the "Shuttle" living and work space. During the five-day mission, research in far-infrared astronomy was conducted by a team of two experimenters and two pilots who flew a total of seven flights. The entire team was constrained to the aircraft and the ground-based complex for the five-day period.

An ongoing Lear Jet astronomy program was selected for the first simulation mission in order to activate the ASSESS Program quickly, effectively, and economically. The objective of the ASSESS mission (apart from the scientific objectives) was to obtain preliminary information on various aspects of management and operation for possible application to the management and operation of Shuttle experiments. A second objective was to gain experience to more effectively conduct upcoming simulations on the ASO CV-990 aircraft, which more nearly resembles the configuration planned for the Shuttle Sortie Laboratory.

Experienced experimenters were deliberately chosen, and they upgraded their equipment for the constrained mission. Although a few problems developed, they were able to solve the problems satisfactorily within the mission constraints and obtain significant scientific results. Essentially total responsibility for experiment preparation and operation was assumed by the experimenters, within the limitations of safety and the simulation guidelines.

Data were obtained on experiment preparation, type of experiment components, operation and maintenance, data acquisition, crew functions, timelines and interfaces, use of support equipment

and spare parts, power consumption, work cycles, influence of constraints, and schedule impacts. The significant results of the simulation mission were as follows:

1. The mission was initiated and successfully implemented in a period of four months. Significant, new scientific results were obtained by use of a blend of new and upgraded equipment developed specifically for this mission.
2. The participants adapted easily to the simulated Shuttle constraints of this mission.
3. Few equipment problems were encountered during the mission. The experimenters were able to maintain and repair their own experiment without outside support, using tools, parts, and service equipment of their own selection. Experience gained by the experimenters in previous flight research was an important asset in achieving full utilization of the experiment.
4. Compared to previous unconstrained missions by these same experimenters, the physical constraints of the simulation mission helped, rather than hindered, the acquisition of data. The proximity of all necessary life and experiment support facilities resulted in a more directed and concentrated research effort.
5. The experimenters had complete responsibility for the design of the experiment and its reliable operation. They chose to enhance the capability of the experiment by redesigning and fabricating several new units. They also built back-up units for the more critical components, to insure reliability. The majority of the equipment was built in the experimenters' laboratory, one unit was a custom-commercial item, and the re-

mainder were standard commercial products.

6. The performance evaluation of the experiment in the home laboratory consisted entirely of operational tests; no environmental or long-term reliability testing was done. This procedure was considered adequate in the present case since the basic experiment had been operated and proven reliable in previous flight research.
7. Simulated ground-based environmental tests of the experiment were accomplished after installation by means of a series of unconstrained checkout flights prior to the mission. Initial equipment problems were resolved during that time.
8. The work-rest cycle of the simulation crew was built around the mission schedule. About 10 hours per day were spent by the experimenters in experiment-related activities, including flight time, and 6 hours were available as free time. On a per-flight basis, about one-half of the time was preparation and one-half was flying; the observation (data taking) period amounted to about one-fourth of the flight time.

Analysis of the data taken prior to and during the simulation mission indicated specific areas of relevance to Shuttle Sortie mission planners. Recognizing the limits inherent to generalization from one set of results, the following pertinent observations were made:

1. Given no crew duty-cycle constraints, the experimenters did not pre-plan their work-rest schedule, they slept in short periods between other activities, and they maintained themselves in satisfactory physical condition throughout the mission.
2. Close flight-crew/science-crew interaction proved highly

valuable in accomplishing the objectives of the experiment.

3. The intimate working relationship between the experimenters and their equipment assured immediate discovery of equipment anomalies, without the use of automatic monitoring equipment.
4. The experimenters felt strongly that maximum useful data recording was achieved by selecting targets on a day-by-day basis, the selection thus reflecting the accomplishments of all previous target selections.
5. There was no requirement for a data-down link during the mission. All data were recorded on board in the form of cassette tape recordings and hard-copy printout; the total quantity of tapes and hard-copy printout was easily manageable.
6. For this mission, the experimenters were not limited to any number or weight of tools and spare equipment. As a result, the experimenters assembled a large number of test devices, spare parts, and tools. Minimal use was made of the large inventory they requested.
7. Operation of this instrument required constant attention of two experimenters. On a 24-hour-per-day basis on a Shuttle Sortie mission, four experimenters would be required working 12-hour shifts. The equipment and associated work space would probably occupy less then half the Sortie Laboratory volume.

FOREWORD

Airborne research has been ongoing at NASA's Ames Research Center for a number of years using mainly a CV-990 four-engine jet aircraft. A unique feature of the operation is the method by which experimental scientists have been blended into active participation to create a very successful arrangement to carry out a wide variety of airborne scientific missions at relatively low cost. More recently, a Lear Jet and a C-141 aircraft have been added to handle airborne infrared astronomy programs. The C-141 will carry a dedicated 91-cm infrared telescope.

As the Space Shuttle Sortie Mode Program has begun to develop, very strong interest has centered on the management approach used by the Airborne Science Office (ASO) at Ames, because comparisons of the methods currently followed in performing science experiments in spacecraft and in aircraft indicate that substantial savings in cost and preparation time would result if the management of Space Shuttle experiments followed the Airborne Science approach. Also, it has become apparent that if manned science research in space is to be strongly supported by the scientific community, the scientists must be deeply involved in all aspects of that research. The success of the Airborne Science Program has been to a large extent due to this direct scientist involvement. In the airborne program, the experimental scientists not only have the responsibility to construct and test their equipment, but also they assist in the installation and participate in flights to obtain the scientific data.

As a consequence of the interest in behalf of Shuttle, a two-phased program has been started to observe and document the experience of the Ames ASO in conducting scientific missions with aircraft. The results will be analyzed to show the form and effectiveness of experiment-management practices for the

purpose of translating this experience into the Shuttle Sortie Program. One phase of the study will cover ongoing conventional airborne missions. The second phase of the study will include several airborne missions constrained to simulate Shuttle Sortie scientific missions. Initially the simulation missions will utilize the relatively simple Lear Jet airborne system, to be followed by CV-990 missions involving several complex experiments, and later the C-141 with the large infrared telescope representing a dedicated Shuttle Sortie Laboratory.

In the simulation missions, scientific data will be taken as in normal Airborne Science operation, but the experimenters and some of the flight crew will be confined for a five-day period in a manner which simulates, to the extent possible, the confinement during a Sortie mission. The degree to which an experimenter, operating under such restricted conditions, can obtain scientific data useful for his valid research problem will be observed against a background of information relating to the selection, preparation and installation of experiments. Particular attention will be given to the participation of the experimental scientist in each experiment--his preparation and testing of equipment; his use of tools, checkout equipment, and spare parts during the simulation; his operation of the experiment; the extent of his "in situ" reduction and analysis of the data; and the corrective actions required to maintain successful operation of his experiment during the simulation.

This program has been termed ASSESS (Airborne Science/Shuttle Experiments System Simulation). An ASSESS Working Group has been formed to guide the program, composed of representatives from NASA Headquarters, Ames Research Center, Manned Spacecraft Center, Marshall Space Flight Center, and Kennedy Space Center.

INTRODUCTION

This report covers the first Shuttle Sortie mode simulation using a Lear Jet aircraft. The application of a very small aircraft such as the Lear Jet to simulate Shuttle Sortie mode operation no doubt first strikes the reader as an anomaly and an explanation of this approach is in order.

In considering the proper approach to conduct simulations of Shuttle Sortie operation using aircraft, the ASSESS Working Group first concentrated on application of the CV-990 since it somewhat resembles the Sortie Laboratory in size; thus, it is possible to confine the experimenters along with their experiments, tools, checkout equipment, spare parts, etc., aboard the aircraft as will be the case in Shuttle operation. However, it was recognized that initiating this new program with appropriate constraints using the CV-990 to properly simulate Shuttle operation would require several months lead time. It was also recognized that even though the Lear Jet is a small aircraft which accommodates only two experimeters with a single experiment, the principles of experiment management and operation are similar to the more complex CV-990 system. Further, it would be relatively easy and inexpensive to divert a team of investigators already committed to the ongoing infrared astronomy program on the Lear Jet to a constrained mission to simulate Shuttle Sortie. Thus, a decision was made to precede CV-990 simulation missions with two or three constrained Lear Jet missions, while at the same time preparation of the CV-990 could proceed.

The combination of two pilots and two experimenters on the Lear Jet somewhat resembles the early "2-plus-2" arrangement initially discussed for Shuttle Sortie. Also, it was felt that significant initial results could be identified rather

quickly and easily for benefit of Shuttle planners, and that important experience could be gained in order that constrained Shuttle missions using the more complex CV-990 airborne laboratory would achieve maximum results.

Thus, for this first Shuttle simulation using the Lear Jet as the flying laboratory, two experimenters, along with the pilot and copilot, were restricted from direct contact with other personnel for a five-day period. During the flights, authentic scientific data were taken in a manner similar to ongoing Airborne Science flights.

In order to carry out the confinement constraint during periods on the ground, the experimenters and pilots were confined to a contiguous complex consisting of the airplane, a work trailer, and a living trailer. This simulation complex was located remotely from other aircraft operations to minimize distractions.

Only the experimenter, hardware, management and operational interface aspects of the scientific effort were studied. Observation and documentation of the psychological or physiological factors were specifically excluded insofar as possible from the study objectives of the ASSESS program. Although these factors obviously cannot be fully excluded, especially when dealing with confinement of human beings, it is not the intention of the program to attempt to obtain or analyze data in that regime.

This report describes the experiment, the facilities, and the operation. The results are discussed and analyzed from the standpoint of their possible use in aiding the planning for experiments in the Shuttle Sortie Laboratory.

SIMULATION MISSION PLAN

GUIDELINES

At the outset of the first Lear Jet simulated Shuttle Sortie mission, the following significant guidelines were established:

1. The mission would involve authenic research in infrared astronomy.
2. The simulated Shuttle constraint period would be five consecutive days.
3. For this mission a total of four people would be constrained, consisting of two pilots and two experimenters.
4. Experienced experimenters would be chosen for this simulation mission, to minimize complications for the new program.
5. Since a Lear Jet aircraft is not large enough to reasonably accommodate the flight personnel in a constrained mode on a continous basis for five days, a simulation complex would be provided consisting of a combination of the aircraft with contiguous trailer arrangements to provide work space and living quarters during non-flight periods.
6. The mission would involve as much flight time as possible. Two flights per night were chosen as a practical objective.
7. The experimenters would be given freedom to construct and/or modify and check out their equipment as they saw fit, with the understanding that the equipment would be expected to operate trouble-free for the five-day period. (This liberal approach was taken to get early data on the extent to which the experimenter would go to insure success throughout the "Shuttle" period.)

8. No limitation would be placed on the type or quantity of test equipment, tools, or spare parts the experimenter could take on the mission. However, once the simulation started, no additional equipment, tools, or parts would be permitted.
9. Environmental check-out of the experiment (normally performed for space-flight hardware) would be simulated by approximately one week of unconstrained aircraft flights with the experiment.
10. Totally open communication would be maintained with the participants relative to data taking for ASSESS purposes. Tape recorders would be used in the simulation complex to record events. The copilot (an astronaut) would serve as an ASSESS observer during flight and on the ground, in addition to his copilot duties. No cameras or television surveillance would be used to record individual activities.
11. A telephone link would be provided in the simulation complex. Use of the telephone was completely unrestrained not only for operational needs, but particularly to determine the extent to which the experimenters would take advantage of a simulated "Shuttle-to-ground" communications link for science and data needs.

No attempt was made to control or guide the experimenters in the manner in which they prepared or operated their experiment, except for safety considerations and the limits imposed by the mission simulation constraints and guidelines. There are, of course, natural unavoidable limitations involved in any simulation, and the limitations imposed by using aircraft to simulate Shuttle Sortie mode operations are recognized.

ORGANIZATION

Management

The scientific research for this simulation mission was managed, for the most part, in the manner normally followed in the Airborne Science Office (ASO) for the ongoing Lear astronomy program. The regular mission manager acted as coordinator for the experimenters in installation and check-out of the experimental apparatus. For the simulation period, a mission-control center was set up in a separate room in the ASO about one-half mile from the simulation site. All contacts with the "Shuttle" crew were handled by telephone through the ASO Mission Manager. The mission-control center was manned 24 hours per day throughout the mission. With the exception of aircraft-maintenance personnel and food-service personnel, direct personal contact between the "Shuttle" crew and others was not permitted.

Experimenters and Flight Crew

The two experimenters were chosen from the ongoing infrared astronomy program using the Lear Jet aircraft. To minimize complications on the first of the simulation missions, a pair of experimenters was selected who were experienced and had been successful in the program. Airborne Science activities have proved that new experimenters require several missions to approach trouble-free mission operation, and it was decided that experienced experimenters properly represent Shuttle participants who would be reasonably trained.

The pilot was provided by the Flight Operations Branch of Ames Research Center. The copilot was a scientist/astronaut already associated with the ASSESS program, from the Manned Spacecraft Center. He also acted as ASSESS observer during the mission, to provide data on the various aspects of experimenter and equipment performance pertinent to the ASSESS program.

Support Personnel

Support for the mission was received from a number of groups at Ames Research Center. Installation of the experiment in the airplane was done primarily by the Metals Fabrication and Aircraft Services Branches. This work was monitored by the Research Equipment Engineering and Aircraft Inspection Branches, and the Airworthiness and Flight Safety Group. Supplies and equipment were provided by ASO laboratory personnel. During the simulation flights, the ASO flight planners, the Flight Operations Branch, the Aircraft Services Branch, and the Aircraft Inspection Branch all provided support for the mission.

SCHEDULE

In planning for the simulation mission, the time to be allotted for preparation and check-out of the experiment was chosen jointly by ASO personnel and the experimenters. This period was about 3 1/2 months. It was planned that one week be allotted for check-out flights for the experiment, one week for the mission, and an additional week following the mission for unconstrained data acquisition in the event that the simulation constraints prevented or restricted adequate scientific data acquisition by the experimenters.

The target date for start of the simulation mission was chosen to coincide with appearance of the new moon. At this time, interference from background moonlight is minimum, and this is the best period for viewing other astronomical objects.

OPERATIONS PLAN

Facilities

The simulation complex consisted of the Lear Jet aircraft and two trailers. The complex was located in a relatively isolated parking lot well removed from other flight operations activities. The site and adjacent roadways were blocked

off from casual traffic. From the site, the aircraft could either be towed to the hangar area for maintenance or taxied to the runway for flight. Refueling, preflight checks, and minor maintenance were performed at this location, except when rain forced these operations to be done in the hangar area. Figure 1 is a general view of the complex with the aircraft in taxi position. For experiment upkeep the aircraft could be parked alongside the trailers, as shown in the simulation-complex layout of Figure 2. The area was illuminated with flood lights to permit aircraft servicing at night.

The aircraft was a Lear Jet, Model 23 (see Figure 3). At maximum gross weight, the climb to altitudes of 40,000 and 50,000 ft. for this aircraft takes about 15 and 50 minutes, respectively. Cruise time at altitude varies from about three hours at 40,000 ft. down to 40 minutes at 50,000 ft., at true airspeeds close to 450 knots. For the mission flights, cabin altitude was varied up to 25,000 ft. and required that oxygen masks be donned prior to takeoff. Experimenters' equipment weight was limited to about 600 lbs. The main cabin of the aircraft has a volume of only about 150 cubic ft. and space is at a premium; it is barely possible for two experimenters to work in this confined space for the 2 to 3 hour flight duration. Figure 4 illustrates the research environment.

The aircraft intercom system was modified to give the copilot/observer the added options of a "hot-mike" loop with the experimenters and a private tape recorder system, as well as to allow recording of all communication within and from outside the aircraft on a common recorder. Although the original purpose of the change was to facilitate ASSESS observations, it also proved beneficial for coordinating flight activities.

Accommodations for the pilots and experimenters consisted of two separate units, the living quarters and the work area. The former was a standard 8 by 26 ft. air-conditioned vacation trailer with four separate beds and the usual facilities. Windows were covered for daytime sleeping. The work area used by the pilots and experimenters was a 10 by 24 foot space in a standard office trailer. A partition separated the work area from a service and storage area which was not used by the participants. Figure 2 illustrates the placement of these units and shows the arrangement of facilities and furnishings. Figure 5 is a photograph of the experimenters' bench in the work area.

Logistics

The logistics plan for the mission dealt primarily with "Shuttle" utilities, life-support systems, and aircraft operations. It was assumed that all supplies for maintenance of the experiment would be onboard at the start, as specified in the mission guidelines. "Shuttle" utilities were electrical power and cryogenics. Electrical power entered the simulation complex at the main distribution panel in the service area at 60 Hz and 220 V; the experiment required 60 Hz at 115 V, 400 Hz at 115 V, and 28 VDC. A portable power cart was used to convert line power to 28 VDC for input to the aircraft systems, or to the work area. Aircraft inverters provided the AC power for the experiment, when it was installed. AC power was provided in the work area by stepping down line voltage at 60 Hz, and by a small 28 VDC to 400 Hz converter placed in the service area.

The other "Shuttle" utility was cryogenics. LHe and LN_2 were supplied in 50-liter quantities, along with high pressure (3000 psi) bottles of helium and nitrogen gas. Additional quantities of cryogenics would be supplied if needed.

Life support systems installed at the simulation complex were electric power, city water, and sanitary sewer service. The living quarters and work area each had its own air-conditioning and heating system. Solid-waste containers were located outside the living quarters.

At the start of the mission, the living quarters were well stocked with linens and paper supplies, cleaning supplies, eating and cooking utensils, and supplemental food supplies. The plan was to deliver two meals a day (morning and noon) from the Ames cafeteria and store frozen food onboard for the third. Meals would be ordered by telephone, through mission control; selection to be made from the cafeteria menu. A supply of airline-type frozen meals was purchased and stored in a central location, for delivery once a day to the complex. The time schedule for eating was not planned in advance, but was left open for the simulation crew to decide.

Weather permitting, all flights were to originate from the simulation complex. Thus, all supplies and equipment required for operation, inspection, and routine maintenance were to be made available at the site. Plans were made to deliver approximately 800 gallons of fuel for each flight. Breathing oxygen and other consumables would be on hand. If for any reason the aircraft was at the hangar prior to flight, the crew would be transported there by car when it was time for the preflight checkout, and returned to quarters at the completion of post-flight experiment maintenance.

Mission Operations

Mission-related operations were scheduled for the week prior to the starting date. Experiment installation was to begin on Monday, with the first checkout flight early Wednesday evening.

On Thursday a rehearsal of all preflight, flight and post-flight experiment and aircraft operations was scheduled at the simulation site, with a checkout flight in the early evening. Friday was to be the day for final tune-up of the experiment and the aircraft, with the weekend free for rest and relaxation. The plan called for the simulation mission to begin after a briefing session on the following Monday at 2 p.m. At this time, the pilots and experimenters were to move to the simulation complex and base there throughout the mission until the debriefing meeting scheduled for 9 a.m. Saturday. All mission activities were to be coordinated through the mission-control center. All contacts with the "Shuttle" crew would be handled by telephone through the ASO Mission Manager or, in his absence, through the ASSESS representative on duty. With the exception of aircraft-maintenance and food-service personnel, direct personal contact between the "Shuttle" crew and others would not be permitted.

The ASO Mission Manager for the Lear Aircraft Program was to serve in his normal capacity as focal point and coordinator for any problems that occurred, in addition to the day-to-day arrangements for overall operations. Flight planning would be handled in the normal manner by the ASO Flight Planner, on a day-to-day basis as requested by telephone from the experimenters, using information on possible targets and scheduling furnished at the start of the mission, as well as current input from the experimenters. Completed flight plans would be posted in the work area at the simulation complex, without direct contact with the "Shuttle" crew.

The daily time schedule of mission operations was completely at the discretion of the simulation crew. Target selection, flight request, experiment maintenance, eating and sleeping, etc., was entirely open at the start of the mission. The immediate preflight, flight and post-flight activities were defined in a

detailed Flight Operations Plan formulated by the Aircraft Commander; all activities and safety precautions were listed.

The plan for aircraft ground operations was to refuel, perform minor maintenance tasks, and make safety inspections at the simulation site. Departure and recovery also would occur here. Arrangements were made to taxi under power between the simulation site and the airfield.

Support Operations

Insofar as possible, the support operations plan followed the procedures normally used in the ongoing Lear research program. Overall coordination is provided by the ASO Mission Manager, the focal point of the operation. He initiated the requests for aircraft services and flight-crew support. For this simulation mission, the special support activities related to the remote site, the life support function, and the round-the-clock schedule were planned in cooperation with the ASSESS Program Manager and representatives of the various support groups.

The Aircraft Services and Inspection Branches of Ames were requested to serve and maintain the aircraft while based at the simulation complex, on a 24-hour-a-day basis, and to add to the normal spare parts inventory replacements for several critical items whose failure would interrupt the mission for one day or more (delivery time from supplier). Special preventative maintenance was done on the aircraft prior to the ASSESS mission to avoid, insofar as possible, a mission failure due to aircraft problems. The aircraft maintenance crews consisted of two mechanics, one electrician, and one inspector; each crew to work a 12-hour shift, starting at 6 a.m. Ames' vehicles were available for aircraft refueling and standby fire protection, as well as to accompany the aircraft along the taxi path from the simulation site to the airfield taxiway and return. Only in the event of a malfunction requiring special services, or adverse weather conditions,

was it planned to bring the aircraft to the hangar.

Support activities of the Ames Flight Operations Branch were mostly their normal functions, adjusted to the time schedule of the simulation mission. The Aircraft Operations Office is normally in continual radio contact with the aircraft while in flight and within radio range. The duty officer is expected to monitor local weather conditions, to relay messages, to advise the ground crew of expected landing time, and to call to the office (for direct communication) any person requested by the flight crew. Aircraft commanders and back-up pilots are assigned to research missions by the Flight Operations Branch, at the written request of the ASO Mission Manager. Normally, a different individual would serve as Command Pilot each night; in this case the entire flight series, including pre-mission checkout flights, was assigned to one person, to achieve the maximum continuity in the research effort, both in the scientific program and in the ASSESS simulation experience. The Aircraft Commander participated actively in the operations planning, accepting responsibility for special taxiing arrangements relative to other local Flight Operations and for a detailed aircraft activities schedule and safety program to be used before, during and after flight. He also was asked to monitor the physical condition of the experimenters and to judge their fitness for flight, as well as to verify that the aircraft life-support O_2 system was maintained in "top shape."

The Ames Security Branch supported mission operations by arranging for the use of roads for aircraft towing and taxiing, and by planning traffic control measures, site isolation, and night security patrols. Security guards were notified 30 minutes before takeoff or landing to allow time for road blockades to be set up along aircraft taxi paths.

Support for aircraft navigation and flight planning was provided by the ASO, using normal procedures. The request for flight

originates with the experimenter who submits his request to the ASO Mission Manager. When approved, it is passed to the ASO Flight Planner for implementation. After checking with the FAA Center and others for clearance, the Flight Planner returns a completed flight plan to the Command Pilot. The plan is approved by the pilots in consultation with the experimenters and filed by telephone with local Flight Operations. ASO ASSESS personnel made the necessary arrangements for food supply during the mission, and for other logistics related to ASSESS observations.

Safety

Flight safety is of prime importance in all ASO operations, and normal precautions for the protection of personnel and equipment are well established. Safety requirements applicable to experiment design are given in the Lear Experimenters' Handbook.

Several individuals, as well as specific Ames organizations, interface with the Lear Jet experiment to insure a safe operation. The ASO Mission Manager has an implied role, as manager of the overall program, to identify and correct any design or operational deficiency which may be a safety hazard. The experimenter himself has perhaps the greatest concern for experiment safety since he participates in every flight. In a similar vein, the pilot as well as the copilot take a personal interest and get involved extensively to insure safety.

The Aircraft Inspection Group is charged with a specific responsibility for safety. They continually inspect the experimental installation as well as the aircraft prior to every flight to insure that all routine inspections and parts replacements are made on a timely basis and that any identifiable safety concern gets proper attention. They have the authority to suspend operations if unsafe conditions are not corrected. Finally, the Airworthiness and Flight Safety Review Board (AFSRB) has a broad overall safety responsibility, and, utilizing the Airworthiness Engineering Group,

they continually oversee all designs and operational plans as they progress toward actual installation and operation. They specifically investigate in depth any unique new design, including the stress analysis.

Of particular significance is the fact that a detailed review is presented to the AFSRB prior to every major or unique aircraft mission covering thoroughly all new designs, operational plans, contingency considerations and any other facet associated with safety. The presentation is usually made by the ASO Mission Manager; however, other key individuals participate, such as the pilots, designers, ground operations personnel, and representatives of the Airworthiness Engineering Group. If appropriate, the experimenter may also participate. Long lead time designs are generally reviewed by the AFSRB at least once well in advance of the pre-mission review. The Chairman of the AFSRB specifically issues approval of the aircraft mission before implementation.

In the case of the Lear Jet infrared experiment, since the telescope installation has been basic to a number of missions by several teams of experimenters, it had been reviewed deeply by the AFSRB well before the ASSESS mission. Thus, the AFSRB review for this mission concentrated on the unique features of the experimenters' sensing equipment and the mode of flight operation, as well as the considerations for personnel constraints and operations from the simulation site.

Normally, the ASO requires new experimenters in the Lear program to take a one-day, high-altitude training course and altitude chamber test routinely given at several military installations, and to attend a local training session on Lear life-support systems and emergency procedures. In the present case, both experimenters had taken the prescribed training earlier and, because of extensive flight experience with the ASO, were completely familiar with the

safety procedures. Both men satisfied the requirements for a current FAA Class II flight physical certificate (or equivalent), an electrocardiogram, a current high-altitude certificate, and a satisfactory condition of health. Both experimenters were given an examination by an Ames approved physician immediately prior to the start of the mission.

A list of the significant operational safety rules which applied to the ASSESS mission are as follows:

1. Aircraft would not depart the simulation site if weather forecast made return to Moffett Field questionable.
2. Alternate recovery sites would be chosen before flight, to be used if adverse weather conditions or other emergencies develop.
3. All final approaches would be radar "handoffs" to Moffett GCA.
4. Flight Operations Office radio operator would continuously monitor the aircraft communication frequency during flight.
5. Pilot not flying the aircraft would check and report on O_2 system every 5000 ft. during climbout.
6. During periods of astronomical observation when the copilot is in the experimenters' communication loop, the Command Pilot would monitor the O_2 life-support system.
7. The Command Pilot could elect to recover to the hangar instead of the simulation site if he considered it best for safety reasons.
8. The Command Pilot would be responsible for the operation of the aircraft O_2 life-support systems and would assure their proper maintenance.
9. The Command Pilot would be responsible to evaluate pilot and experimenter physical condition and would cancel the upcoming flight if excessive fatigue became apparent.

10. A flight surgeon would be on call at all times and would receive a daily medical report from the Command Pilot.

11. The only allowable medications would be aspirin and nasal spray.

12. Security guards would provide traffic control and a safety vehicle would accompany the aircraft during taxi to or from the airfield taxi strip.

13. A guideline would be painted on the roadway to assist taxi operations; obstacles close to the roadway would be identified with flashing lights.

14. Aircraft refueling would be done a specified distance from the living quarters and in the presence of a fire-protection vehicle.

15. Aircraft would be grounded to a 30 ft. safety ground rod whenever located at the simulation site.

16. Crash and fire crews would be notified of aircraft parking locations, taxi and tow routes.

Contingency Procedures

Procedures for handling contingency situations were part of the Mission Operations Plan. Weather contingencies were of foremost concern, since the aircraft was to be parked outside at the simulation site for normal operation. Fatigue and/or illness of the crew had to be considered, since either could jeopardize mission performance. Provisions had to be made for landings at alternate airfields, which could interrupt the simulation aspects of the mission, and for major aircraft or experiment maintenance problems.

The following contingency procedures were adopted for the constrained period of operation:

1. In the event of a major maintenance problem, or rain, the

aircraft would be stationed in and depart from the hangar. The "Shuttle" crew would be taxied from the simulation site to the hangar by car for each flight.

2. During periods of rain, the cryogenic supply would be located in a building close to the simulation site for filling of Dewars.

3. If a problem with the experiment should require some part or item of test equipment that is not available "onboard", the necessary item would be supplied if the success of the mission was considered to be in jeopardy.

4. The Aircraft Commander could choose to:

    a. Recover to Ames' hangar in case of bad weather or a safety problem.

    b. Cancel the upcoming flight in case of over-fatigue of pilots or experimenters.

5. In the event of illness of either pilot, he would be replaced by the assigned back-up pilot. If one or both of the experimenters becomes ill, the upcoming flight would be canceled and rescheduled.

6. Any decision to cancel the mission would be made by the ASO Mission Manager in conjunction with appropriate personnel.

7. In event of a telephone malfunction at the simulation complex, the ASSESS duty officer would be posted at the site until reestablishment of communication.

8. Alternate landing fields would be used in emergencies; if at a nearby airport, the ASSESS duty officer would retrieve the "Shuttle" crew, and other Ames' pilots would recover the aircraft; if at a remote airport a decision would then be made as to the effect on the simulation mission and plans for subsequent operation.

Documentation

Preparations for the Shuttle simulation mission followed the minimal documentation procedures normally employed in the ASO Lear Research Program. Since this was not a new flight experiment, most of the information normally required of the experimenter was already on file with the ASO Mission Manager and/or with the cognizant stress engineers in the Research Equipment Engineering Branch and the Airworthiness Engineering Group. This documentation included drawings of the telescope and cryogenic Dewar assembly, a cabin layout showing the location and attachment of the experiment to the aircraft structure, a stress analysis of the telescope support structure, and a listing of the experiment power requirements. The design of the experiment followed the guidelines given in the Experimenters' Handbook, the standard reference document which defines experiment interface and design safety requirements for the experimenter.

About five weeks prior to the scheduled start of the simulation mission the Airworthiness and Flight Safety Review Board requested, for safety reasons, that the experiment be moved to the opposite side of the aircraft. The responsibility for the job was assumed by the ASO Mission Manager who, in close cooperation with the stress engineer, the experimenter, and the Chief of the Metals Fabrication Branch, fixed the design, expedited the fabrication, and secured the approval of the Aircraft Inspection Branch and the AFSRB in a period of approximately one week. This was an outstanding demonstration of the quick-response capability inherent in the simple, direct documentation procedures used by the ASO.

The same documentation procedures were used for the ASSESS mission as are normally followed by the ASO. Only two documents were issued for the mission: a work order and a flight request. The aircraft work order calling for installation of the telescope and attendant electronic equipment was issued by the ASO Mission Manager

and served three functions. It was used to notify the AFSRB for review and approval of the safety and airworthiness of the experiment. It was used to authorize fabrication of the attachment hardware. It served to notify the Inspection Branch for inspection and approval of the final installation.

Just prior to the flight period, the ASO Mission Manager initiated a flight request for the entire flight series. This authorizing document circulated to those groups concerned with flight operations. All other coordination and decision-making activities were accomplished by the ASO Mission Manager and the experimenter in informal discussions with representatives of the cognizant support groups.

The somewhat unique operations associated with the Shuttle simulation mission required some documentation in addition to that normally used. A Mission Operations Plan was formulated by the ASO Mission Manager and the ASSESS Program Manager, and a Flight Operations Plan by the Command Pilot. These were submitted to the Airworthiness Engineering Group of the Flight Operations Branch for concurrence, were approved by a full meeting of the Airworthiness and Flight Safety Review Board, and served as the guide for the detailed activities of the simulation mission.

RESEARCH EXPERIMENT

The experiment package was started in 1967. It was designed to fit the Lear Jet, and was installed in October 1968. It became the first experiment to be flown on the Lear Jet in the Ames Airborne Research Program. This program has been devoted almost exclusively to infrared astronomy, and only one experiment is flown at a time.

The experiment has been progressively improved. A two-axis stabilization system was added in October 1970, and a beam-splitter guidance system in September 1971. The guidance-control electronics were modernized in June 1972.

Upgrading of the optical detector and Dewar cryogenic system has been a continuing process, right up to installation for the Shuttle simulation mission.

Basic Instrument

The experiment was designed to use a 30-cm, open-port telescope mounted on the left side of the Lear aircraft as shown in Figure 3. The telescope was supported by a two-axis gimbal ring, the center of which coincided with the center of a circumferential air seal at the telescope-fuselage intersection. The air seal leakage was small enough to allow some cabin pressurization, while permitting ±3 degrees of motion of the telescope about each axis. Figure 6 is a close-up view of the telescope port, showing the spider support for the secondary mirror, the aerodynamic fence upstream of the opening, and a smaller opening for the 10-power guide telescope. A view of the telescope assembly from inside the aircraft cabin is shown in Figure 7.

Infrared radiation passed through an infrared window into a cryogenic Dewar containing an 8-element optical filter wheel, a focusing mirror, and a doped germanium bolometer. The detector was cooled by liquid helium to about 2°K, and was capable of sensing radiation over the wavelength range from 25 to 100 microns.

The signal from the detector was processed electronically and exited to the monitor/recording system in four forms. The signal was split and one part was fed to a strip-chart recorder for analog readout and to an integrating recorder for digital printout. This latter device integrated for a preset interval of time, which was keyed to the experiment timeline by an elapsed-time clock. The other part of the signal was processed through two different voltage-to-frequency converter units, one of which was monitored in audio-frequencies with an earphone, and the other was recorded on one channel of a stereo magnetic tape deck. The second channel of the magnetic tape was reserved for voice comments of the experimenters and intercom messages in the aircraft.

Figure 8 shows the electronic equipment mounted in the cabin.

Modifications

The experimenters modified their experiment for the ASSESS mission to insure successful operation and to reduce the chance of irreparable breakdown during the five-day mission, as would be the case during a Shuttle mission. They accomplished this primarily by building new components to provide replacements for the more critical parts in the event of a failure. At the same time, the experimenters took advantage of the opportunity to make improvements in the design of several components to enhance the performance of the experiment. The new components built to provide replacement parts were as follows:

1. A new cryogenic Dewar was constructed to provide a back-up cooled-detector system. Since the new Dewar incorporated major improvements over the existing unit, it became the flight Dewar, and the older one served as the back-up.

2. Two new electronic amplifiers were constructed to provide back-up units. As with the Dewar, these were of an improved design to increase their performance, and hence, the new amplifiers were used in the instrument, and the existing units served as spares.

3. Back-up secondary mirrors were provided for the telescope.

The changes to improve performance were as follows:

1. The new cryogenic Dewar was built to incorporate the latest development in detector design. The detector consisted of a doped germanium bolometer which gave an order-of-magnitude increase in the signal-to-noise ratio over that of the bolometer in the older Dewar. The cryogenic design of the new Dewar was improved over that of the older Dewar by providing a liquid-nitrogen shroud to reduce the boil-off rate of the liquid helium. This extended the time between

fillings of the Dewar and at the same time reduced the detector thermal noise caused by boiling of the liquid helium. (This certainly represents a typical instrument improvement which might be made for Shuttle use in order to reduce cryogenic servicing requirements.)

2. The design of the two electronic amplifiers was updated to improve their performance. The units involved were the Dewar-sensor pre-amplifier and the signal-channel electronics.

3. An information display was provided for the pilots to show telescope roll and yaw relative to the aircraft, to reduce abrupt flight-path changes which would drive the telescope against the stops.

4. The telescope beam splitter was enlarged to give a wider field of view to the observer, to aid visual alignment with star fields.

5. An adjustment was installed on the beam splitter to balance out telescope incremental offset.

6. Electronic circuits in the telescope stabilization system were modified to give more rapid response.

Experiment Components and Costs

A listing of experiment components, the type of construction, and the estimated power requirements is given in Figure 9. Most of the telescope system was made in the experimenters' laboratory, the IR detector and Dewar were custom-commercial items, and the remainder were off-the-shelf units.

Records of experiment costs are not available. The experimenters estimated that the initial cost of the entire experiment over the period from 1967 to 1969 was approximately $100,000. Additional funding in the amount of $17,000 was provided to permit modifications to be made for the ASSESS simulation mission for increased reliability.

Installation

Installation of the experiment in the airplane proceeded normally, except for one minor problem. When the new Dewar was delivered, the experimenters discovered that the Dewar pre-amplifier was mounted in a position that would bring it too close to the electrical field of the telescope stabilization motor. The amplifier was re-mounted on the Dewar away from the field of the motor, and a plate was machined to cover the previous mounting hole. Otherwise, the installation of the experiment proceeded normally.

The management interfaces associated with the installation are of interest. Initial contacts between experimenters and shop technicians generally are handled through the ASO Mission Manager. However, in the case of the present experimenters, their past experience in the airborne science program has led them to the practice of direct contacts with the support personnel. The mission manager is advised and keeps aware of the work involved, but does not act as an interface to accomplish the work. During installation of the experiment, the experimenters worked primarily with the airplane crew chief. The completed installation, including the modification, was inspected and approved by two organizations: The Aircraft Inspection Branch and the Airworthiness Engineering Group. The inspections were thorough, but the attendant documentation was minimal. The inspectors signed their approvals on the work order that requested the experiment installation. Inspections were for aircraft safety only. No inspections were made by Ames' personnel for performance or reliability of the experiment. This responsibility was left entirely in the hands of the experimenters.

EXPERIMENT SUPPORT

A mission guideline was established not to impose restrictions on the size, weight or number of items of support equipment available for the maintenance and repair of the research experiment; rather, it was decided for this first ASSESS mission to learn what equipment and supplies an experimenter would want to have available.

The only limit on support equipment was that it be at the simulation site at the start of the mission; no addition of any kind would be permitted unless the continuation of the mission was in jeopardy.

As a result of this approach, a very substantial collection of diagnostic equipment, spare parts, tools and service manuals was assembled. An inventory of these items and the furnishings in the work area is given in Figure 10, where the source of supply is identified, and sizes, weights, and quantities are listed. While this latter information is not available for all items, the aggregate weight of equipment carried "onboard" was well over 500 pounds. In excess of 250 maintenance items were either brought in by the experimenters or supplied by Ames at their request. This over-response to the complete freedom allowed the experimenters in their choice of maintenance equipment, parts, etc. was to be expected. Future ASSESS mission planning will incorporate some appropriate limitations.

Test Equipment

Test equipment consisted primarily of general-purpose diagnostic devices for troubleshooting electronic circuits. These were standard laboratory-type devices for use in the work area between flights and were in sufficient quantity and diversity to enable the isolation of system/component faults. Circuit diagrams for experimenter-built equipment and service manuals for commercial units were available, as well as reference documents on cryogenic and infrared technology.

Spare Parts

Spare parts for the experiment fell into three groupings: complete electronic modules, electronic components, and telescope mechanical parts. The experimenters provided back-up units for those mechanical and electronic units which could be quickly

replaced in the event of failure, and which in previous research had proved to be the source of most problems. Thus, repairs could be made when time was available without interruption of the flight schedule.

Tools

The available supply of tools consisted entirely of small, commonly used hand tools. Only a soldering iron and a drill motor required electrical power. The experimenters brought with them an abundance of tools that might be needed.

Supplies

A wide variety of supplies, mostly in small quantities, was available to the experimenters. Part were normal expendables used in the conduct of the experiment, with most of the remainder being items for the maintenance and repair of the optical Dewar and the vacuum pumping system.

ASSESS OBSERVATION PROCEDURES

Several different techniques were used to collect observational data on the simulation mission for the ASSESS Program. The primary technique was to use specially assigned people to make direct observations of the various events in the program. Constraints of the simulation mission, however, restricted the opportunities for direct observation, and other observational techniques were used as well. The copilot was assigned the task of full-time observer during the mission. This task was intended to encompass observations of the experimenters' activities during the flights and during their work periods in the simulation complex. It was recognized that complete coverage of all the experimenters' work activities by the copilot might not be possible because of the copilot's work load and sleep schedule. Therefore, his observations were supplemented by information from three tape recorders. One recorder was installed in the airplane to record the experimenters' and pilots' conversations in flight. The copilot also used a portable hand-held

recorder to make additional observations during flights and work periods in the aircraft on the ground. A third recorder was installed in the work trailer to record the experimenters' conversations during work periods.

To supplement the copilot's observations, three additional people were assigned to observe work done by the experimenters in the aircraft between flights. The work periods of the observers were arranged for round-the-clock coverage of activities of the mission. The observers also gathered the tapes and analyzed the information. In addition, periodic telephone conversations were held with the experimenters and pilots to review developments during the mission. A major source of observational information came from the debriefing session that was held with the experimenters, the pilots, and ASO personnel at the completion of the simulation mission.

A representative of Marshall Space Flight Center participated as a general observer throughout the pre-flight and constrained portions of the mission. He contributed significantly to the ASSESS effort in matching the observations to the objective needs of the Sortie Lab requirements at MSFC.

RESULTS AND DISCUSSION

The Shuttle simulation mission, for the most part, went according to plan. No major problems were encountered. Experiment-preparation delays caused slippages in the schedule totaling three weeks. The delays are considered to have had no significant effect on the results of the ASSESS mission. Very early seasonal rain during the early part of the mission forced the airplane to be moved into the hangar for the first three flights, rather than leaving it at the simulation site. Later in the mission, the weather cleared, and the remaining flights were based from the simulation site.

A total of 10 flights were planned at the beginning of the mission. Seven flights were actually flown. Only one flight was aborted because of an operational problem encountered with the experiment. The other two flights were dropped because in each case the immediately preceding flight overlapped the available viewing time for objects considered for the following flight.

CHRONOLOGY

Events during the period of experiment preparation, installation, and checkout, and those during the simulation mission are listed below in chronological order. Figure 11 illustrates this sequence as an overall mission timeline.

DATE	EVENT
May 9	Tentative choice of experimenter team.
	Initial discussions with experimenters.
	Survey of site and facility requirements completed.
	Tentative mission dates Sept. 24 to 30.
June 15	Experimenters notified of selection.
July 14	Final definition of experiment modifications.

DATE	EVENT
August 1	Funding approved for experiment modifications.
4	Test site selected, preparations started.
14	Experimenter orders new cryogenic detector.
16	Site and facilities design completed.
25	On-site experiment support equipment list submitted. Experimenter requests delay of one week, to allow completion of cryogenic detector. ASO made decision to provide at least two weeks. Start of mission tentatively scheduled for Oct. 9.
Sept. 15	Site and quarters preparation completed.
Oct. 2	Experimenter arrives and begins installation.
5	Installation of experiment completed except for new cryogenic detector. Briefing to Airworthiness and Flight Safety Review Board. Plan of operation approved. Crew physician assigned.
6	Cryogenic detector not finished. First check-out flight made with back-up detector. Targets Jupiter and M-17. Starting date set for October 13.
7	Principal Investigator arrives with new cryogenic detector (Dewar).
8	Physical location of preamplifier mounted on Dewar not satisfactory. Corrected with assistance from Ames' machine shop personnel.
9	Second check-out flight originates from hangar because of rain. Full simulation crew aboard for first time. Targets Jupiter and M-17.
10	Damage to new detector by a blockage during boil-off; flown to experimenters' laboratory for repair. Check-out flight (back-up detector) aborted because of electronics problems.

DATE		EVENT
Oct.	12	P.I. to home laboratory to align optics in repaired detector. Starting date established for Oct. 16.
	14	P.I. returns to Ames with detector. Third check-out flight, from hangar because of rain. Targets Saturn and M-82.
	16	Mission briefing at time 1400.

START OF SIMULATION PERIOD

DATE		TIME	EVENT
Oct.	16	1600	Move operations to simulation site.
		2305	Flight #1 from hangar (rain) aborted; vacuum-hose problem
	17	0500 - 0700	Flight #2 from hangar on schedule (rain). Target Venus.
		2235 - 0105	Flight #3 from hangar (rain) and return to simulation site. Targets Saturn and M-82.
	18	0500 - 0650	Flight #4 from simulation site. Target Venus.
		0900 - 1100	Experimenters locate and repair telescope stabilization problem.
		2235 - 0055	Flight #5 from simulation site; flight extended to increase viewing time. Targets Saturn and M-82.
	19	0055 - 0210	Refuel at Las Vegas, Nev.
		0320	Return to simulation site. Next flight cancelled because extended length of Flight #5 prevented another flight before daylight.

DATE		TIME	EVENT
Oct.	19	1730	Experiment power measurements.
		1825 - 2035	Flight #6 from simulation site. Target Jupiter.
	20	0010 - 0120	Flight #7 from simulation site. Targets NGC253 and M-42.
		2230 - 0130	Flight #8 from simulation site. Targets Saturn, M-82, M-42.

END OF SIMULATION PERIOD

Oct.	21	0900 - 1130	Mission Debriefing.

EXPERIMENTERS' ROLE

The Airborne Science Office research program is designed to facilitate the acquisition of scientific data. To aid in reaching this goal, the experimenters are given a leading role. Furthermore, the ASO procedures are fashioned to encourage participation by a wide variety of experimenters. Such factors as minimal management restrictions and documentation consistent with safe and successful operations aid in facilitating experimenter participation. Along with strong experimenter participation goes a major share of responsibility for reliable performance of the experiment. This philosophy properly places the burden of responsibility on the Principal Investigator.

Before the Shuttle simulation mission, the ASSESS program experimenters had acquired extensive experience in the ASO research approach, having participated in well over 100 flights in the Lear aircraft. As a result, operating under the "Shuttle" constraints proved to be an easy step for them. They were adequately prepared to deal with all aspects of experiment check-out, experiment maintenance, flight planning, and data acquisition and analysis without need for outside help.

Experiment Preparation and Maintenance

An important factor that helped to minimize experiment problems during the simulation mission is that the basic experiment had been operational in one form or another for about four years, and had been used extensively in the Lear airborne program during that time. Operating from this base of experience, the experimenters limited their laboratory test procedure to operational check-out of those mechanical components and electronic modules which had been modified for the ASSESS mission. The testing experience of the various experiment components at the experimenters' laboratory is listed in Figure 12. As shown in this figure, all of the tests were operational. In contrast to established aerospace testing procedures, no environmental or long-term laboratory tests were made of any of the new components. Test equipment in all cases consisted of standard laboratory devices. No problems were encountered in any of the tests. The lack of problems undoubtedly reflects the extensive experience of the experimenters.

During the period of pre-mission check-out flights and Shuttle-simulation flights, four problems occurred with the experiment. These are listed in Figure 13. The most serious problem occurred during the "environmental" check-out flights, when an oversight by the experimenters led to a blockage in the exhaust line of the Dewar, thus over-pressurizing it, and damaging the optical components area in the Dewar. The Principal Investigator took the Dewar back to the home laboratory, where the optical system was repaired. This delayed the start of the simulation mission one week. The other problem that occurred during the check-out flight period was failure of an integrated subcircuit in the detector circuit. The experimenters were able to locate the problem, and they replaced the component without delaying the schedule.

During the Shuttle-simulation period, the experimenters were able to complete their scientific objective with only one minor interruption. The interruption resulted from an operational problem that occurred as preparations were being completed for take-off on the first flight. Difficulty was encountered in evacuating the Dewar. The difficulty was traced to a vacuum hose that had inadvertently been pinched by the seat back. When the trouble was finally located, time was running short and the experimenters' viewing window was diminishing. The experimenters attempted to evacuate the Dewar quickly, but too high a pumping rate led to other problems that could have endangered the Dewar, and they aborted the flight as the airplane was taxiing out to the runway. If this problem were to occur during an actual Shuttle mission, it would have caused only a minor operational delay.

A second problem occurred during the Shuttle-simulation period that apparently had no effect on the acquisition of data. The problem involved the gyroscopic stabilization system for the telescope. The yaw-axis gyro was found to be mis-aligned. It was the belief of the experimenters that this had occurred in shipment of the telescope. The mis-alignment created difficulties in tracking objects with the telescope and required abnormal attention by the experimenters during data acquisition. Although the problem arose during the check flights, the experimenters at first attributed the difficulty to aerodynamic loads on the telescope imposed by the new location of the telescope on the left side of the airplane. Thus, the stabilization difficulties had persisted from the beginning of the mission; however, the problem was not solved until after the fourth flight, at which time aerodynamic loads were dismissed as the probable cause of the problem. Although the problem had been troublesome, the experimenters reported no loss in data because of it. It is of

significance that the experimenters were able to diagnose and repair this malfunction during the mission without requiring outside help.

Scientific Data Acquisition and Analysis

It is not the purpose of this report to discuss the scientific aspects of the scientific data obtained during the mission, and although the quantity of data taken was not voluminous by standards of spacecraft data acquisition, nor was deep analysis performed by the experimenters, there are some aspects of this subject which deserve limited comment.

Having the Principal Investigator participate in the actual collection of data made the most effective use of the flight opportunities. The Principal Investigator was best qualified to plan and accomplish each series of measurements. Following each flight, the experimenters briefly analyzed the data just acquired. The results guided their selection of targets for the following flights. Thus, the acquisition of data became an iterative process, with the experimenters having an essential part in the flight planning.

An important achievement during the mission, apart from the prime ASSESS program objective relative to Shuttle, is the fact the experimenters claimed three scientific accomplishments, as follows:

1. The first infrared observations were made of galaxy M-82 at 100 microns.

2. High resolution scans were made of Orion (M-42), providing new information on its size and structure.

3. Data were obtained on the effect of atmospheric absorption on the multicolor photometry of Venus.

SCHEDULE IMPACTS

Several unexpected events had an impact on the planned schedule for the simulation mission. The original schedule was negotiated with the experimenters and was estimated to allow sufficient time for completion of all construction and check-out of equipment before start of the mission. However, administrative red-tape, both Government and University, severely delayed the transfer of funds to the experimenters. The funds were finally made available to the experimenters less than eight weeks before the scheduled start of the mission. This lead time proved too short for procurement of the new custom-made cryogenic Dewar. Even with a two-week extension, the time was unrealistically short to build and check out a major piece of equipment such as the Dewar. The work was rushed in an attempt to meet the new schedule. The work pressure may have been a factor in the human error that resulted in damage to the Dewar, which caused a third week's postponement for repairs. (See Figure 13.)

The remaining events that affected the schedule were of much less importance, and deserve only brief comment. None of these caused any delay in the schedule.

The first flight was aborted because of a pinched vacuum hose. (See Chronology and Figure 11.) This is a problem that probably has little relationship to the "Shuttle" mission. It was caused primarily by the extremely crowded condition of the Lear cabin, but it does point up the need for great care in organization of equipment under very crowded circumstances.

On the night of October 18, two flights were scheduled, according to the original plan. However, on the first flight (Flight No. 5), the experimenters were obtaining excellent infrared measurements of galaxy M-82--the first of their kind--and, in order to extend their measurement time, they and the pilots decided, promptly, to forego the second flight.

The airplane then landed at Las Vegas, Nevada, for refueling. This was a minor departure from the original plan to land at Moffett Field at the end of each flight.

On the last night of the simulation mission, the viewing windows available for the astronomical objects of interest to the experimenters precluded the possibility of more than one flight. Therefore, only one flight (Flight No. 8) was scheduled, representing another departure from the plan of two flights per night.

"SHUTTLE-TO-GROUND" COMMUNICATION LINK

Communication between the "Shuttle" experimenters and ground-support personnel falls into two categories, (a) experiment management, including equipment operations, and (b) data considerations, including data transfer and communications regarding data retrieval or interpretation with colleagues. All experiment-related communication during this particular Lear simulation mission was of the management type; no data discussion or transfer took place.

There were two modes of communication available to the experimenters during the mission; inflight radio to ground, and the simulation complex telephone. The former was never used by the experimenters, and the only experiment-related telephone calls from the simulation complex were to mission control. Most of these calls concerned navigational planning for upcoming flights. The absence of data-oriented communication for this mission is understandable because the data quantity could be easily handled within the simulation complex and the single prime investigator was "onboard". Thus, he did not need consultation with others regarding the data or other science-oriented considerations. Also, there were relatively few experiment problems which might require supporting information from an outside source.

Data storage was no problem during the five-day period, because only 16 magnetic tape cassettes, eight rolls of strip-chart paper and a few feet of digital-printout record were accumulated.

The only other communication link was the daily delivery of the navigator's flight plan, which was usually posted in the work area when the simulation crew was asleep.

INFLUENCE OF CONSTRAINTS

Because of the exceptionally early and unplanned-for rain, the simulation constraints had to be relaxed to a minor degree. As mentioned before, the aircraft was based at the hangar, rather than at the remote complex for the first few flights. This was done to protect the telescope system from excessive exposure to water. The rain also forced the experimenters to refill their Dewars inside the building adjacent to the simulation complex, rather than in an exposed area within the simulation complex, as originally planned. Filling the Dewar in the building proved to be so convenient for the experimenters that they continued this practice throughout the mission, even after the rain stopped. Relaxation of the constraints was judged not to have affected the mission to any significant degree from a simulation standpoint.

Of primary concern to the ASSESS study is the influence of the constraints on the scientific aspects of the mission. The experimenters stated at the post-mission debriefing that, on the whole, the constraints aided, rather than hindered, their acquisition of scientific data. Having living quarters and meals close at hand was a convenience that permitted additional time for data work-up, experiment planning, and equipment preparation. Furthermore, having test equipment and tools readily accessible in the simulation complex, rather than having to search the laboratory or hangar for a meter or a wrench, also proved convenient.

These conveniences allowed more data to be obtained in a shorter period of time than under unconstrained conditions.

USE OF SUPPORT EQUIPMENT AND SPARE PARTS

At the end of the simulation period, the experimenters identified from the list of Figure 10 those items that had been used in experiment support. Except for the furnishings in the work area, the equipment utilization factor was relatively low, partly because problems with the experiment were few. Figure 14 summarizes the utilization of spare parts and support equipment. With one minor exception, none of the spare parts or electronic back-up units were needed to operate the experiment in flight. The one instance occurred when a phase-lock amplifier was interchanged with a spare unit during a troubleshooting session; the original unit was found to be operating properly, and the source of trouble was located elsewhere. Less than one-fifth of the tools, and just over one-third of the test equipment were used. In contrast, nearly one-half of the expendable items was used. The supply of the more regularly used items (recorder paper, tape cassettes, and liquefied gases) was about half consumed during the mission (Figure 10).

EXPERIMENT POWER CONSUMPTION

The power requirements of the test equipment were estimated by the experimenters, and are shown in Figure 9. The numbers are given in terms of 28 VDC power, although the oscilloscope and the recorders were fed by 60 Hz, 115 volt inverters. These listed values of power were used in the design of the experiment. The specified available power limit was 70 amps at 28 volts. A 9 amp margin was retained to allow for starting surges and occasional extra loads such as a soldering iron or an oscilloscope.

A survey of power available to the experiment, and that used by the experiment is as follows:

POWER AVAILABLE TO EXPERIMENT			POWER USED BY EXPERIMENT		
Type	Source	Volt-Amperes	Type	Users	Volt-Amperes
400 Hz 115 V	Aircraft Inverter	750	400 Hz 115 V	Teles. Gyros, Solenoid Valves, Cooling Fan	12
60 Hz 115 V	Aircraft Inst. Supply Inverter	250	60 Hz 115 V	Recorders and Oscilloscope	190
60 Hz 115 V	Experiment Inverter (built-in)	50			
28 VDC	Aircraft Generator *Less that supplied to AC inverters	1960*	28 VDC	Inverter Losses (∿70% efficiency)	87
				Vacuum Pump (full load)	336
				Teles. Torque Motors	588
				Electronic Modules & Misc.	523
	TOTAL	1960		TOTAL	1736

The power-use numbers given in the table are for steady-state operation. Power surges of 5 to 10 percent above these values were observed when experiment units were turned on. In addition, one of the experimenters estimated that the telescope torque motors might draw an additional 280 VA under full load, as compared to the steady-state value of 588.

The largest user of electrical power was the telescope stabilization system (torque motors) at 21 amps, followed by the electronic modules at about 18 amps, and the vacuum pump at 12 amps (max.). Direct current at 28 volts was almost 90 percent of the power used, while 60 Hz, 115 V accounted for 11 percent, and 400 Hz, 115 V only 0.7 percent. While the original estimates (61A, 28 VDC) and the measurements (62A, 28VDC) agree in total, the distribution of power usage was different than expected. Less power was used by the stabilization system and more by the electronic modules.

WORK CYCLES

Data relative to the experimenters' work-rest cycle and the division of time in various activities are summarized in Figures 15 and 16. The information records did not account for all the time or all the activities during the simulation mission. In particular, it was not practical for the "onboard" astronaut-observer to maintain a 24-hour log-book record of the activities of four people. The trailer tape recorder (originally intended as a primary observing system) did not provide much useful information as hoped. A change from this mode of data gathering for future ASSESS missions is required.

The experimenters' timelines in Figure 15 cover the entire simulation mission. A constant feature of each 24-hour period was a midnight flight (aborted on Oct. 16) which was preceded by a crew-prepared dinner between 5 and 8 p.m., and a preflight planning and checkout period. The morning meal was ordered by the crew each day for delivery at 7:30 a.m. and proved to be the largest meal of the day, in the form of a very substantial breakfast. After the second day the midday meal was eliminated in favor of snack food when desired. Periods of sleep were less regular than meals, rarely exceeded 4 to 5 hours in length, and generally followed the last flight of the morning. The records show one experimenter with near normal total hours, and the other with less than half as much. On October 18 and 20 the rest status of the four crew members was reported to the crew doctor as satisfactory; this was confirmed by comments of the experimenters during the debriefing. In view of the positive attitude of the simulation crew at the end of the mission, and the scientific accomplishments during the period, it is concluded that a successful adjustment had been made to the abnormal work-rest cycle, despite the heavy time demands of the flight and equipment maintenance schedule.

A summary of how the experimenters spent the time is given in Figures 16 and 17. In Figure 16, times are keyed to the flight schedule beginning with the preflight activities, to draw attention to the experiment related effort. Averages for the 8 flights are listed in the last column; approximately 6 1/2 manhours were spent (per flight) in ground activities related to the experiment, 5 1/2 manhours in flight, and 1 1/3 manhours in astronomical observations. Figure 17 shows in graphic form, the average daily activities and the time division of experiment-related activities. On a daily basis, approximately 42 percent of the time was experiment related, 25 percent was free time, and 19 percent was used for sleeping. Of the experiment related effort, 44 percent was in-flight time, of which about 1/4 was observation time; 29 percent was preparation for flight; and 27 percent was maintenance of the experiment between flights. Flight preparation activities are outlined in Figure 18; experiment maintenance time included such things as tuning the telescope stabilization system in the aircraft, making minor adjustments to the guide telescope, changing optical filters in the Dewars, changing batteries in electronic modules, etc.

Average, or typical, timelines of the experiment work flow before and after flight are shown in Figure 18. Routine preparations for flight began almost two hours before takeoff, when the cryogenic Dewars were topped-off with LN_2 and LHe. After a flight there was a shorter period of about one-half hour during which Dewars were changed, emptied, or topped off as the situation demanded. Other pre- and post flight activities generally occurred within these time intervals.

Pilot activities during the mission are summarized in the timelines of Figure 19 and the activities chart of Figure 20.

While the daily schedule is similar to that for the experimenters (Figure 15), the pilots averaged about 1 1/2 hours more sleep per day and had about 1 1/2 hours more free time; time that the experimenters used for preparation and maintenance of the test equipment.

FLIGHT PERSONNEL FUNCTIONS AND INTERACTIONS

The "2-plus-2" simulation crew of this first ASSESS mission was well along to being a working team by the start of the constraint period. The previous two weeks of experiment installation, operational check outs, and check-out flights served to familiarize the pilots with the scientific experiment, as well as with the in-flight procedures and coordination required to make astronomical observations. A beneficial and complementary relationship existed between the science-directed background of the pilots and the previous flight experience of the experimenters. Exchange of information between the science-oriented pilots and the flight-oriented experimenters during this period is one factor which contributed significantly to the success of early mission flights. Once into the simulation period, the continued close cooperation in flight planning and operations made possible by living and working together in the simulation complex, together with good intercommunication during flight, contributed directly to the relatively high level of research output, both in amount and quality. In addition, of course, the fact that no health problems were encountered and that relatively few equipment problems arose, allowed the team members to establish a fairly routine schedule with well defined areas of responsibility. This also made for a smooth running operation. Finally, the aircraft support activities were well managed and, despite the unseasonable weather, no delays were occasioned by aircraft related problems. The smooth relations between pilots and

ground crew also enhanced the mission operations.

Flight planning was a daily exercise involving both pilots and one or both experimenters. Astronomical targets were chosen by the Principal Investigator from a list of some 30 possibilities (which the navigator had been given before the mission started) and the navigator was informed of the selection by telephone. The navigator's calculations were later delivered to the simulation complex, and then were factored into the flight schedule in a general planning session. Frequently, the navigator's suggestions were modified to suit the occasion, even during the flight itself.

Command Pilot responsibility, with all that this implies for aircraft operations and safety, rested with that one person during the entire mission. He and the copilot developed a two-mode flight pattern; the departure-recovery mode with both acting as pilots, and the science data gathering mode when the Command Pilot handled all aircraft responsibilities and the copilot became an in-flight Mission Manager who coordinated the research activities with the flight profile.

The copilot who doubled as ASSESS in-flight observer found the job very demanding of his time. He was in direct contact with the experimenters at all times on a "hot-mike" line. He thus followed the progress of the research observations and worked with both the experimenters and the pilot to achieve the best flight attitude and longest track time for viewing the target. He also made a continuous check on safety, an important feature when oxygen equipment is used. He was furnished with a separate tape recorder for noting events and activities relative to the research experiment, but found that there was little opportunity or need for its use. When on the ground, the copilot served as ASSESS observer of the simulation activities, by keeping a log record of what and when things

were done, particularly those having to do with the research experiment, but also the routine activities of daily living. This function proved to be difficult because of lack of coincidence of the observer's and experimenters' schedules. A more effective means of recording this type of information is clearly needed.

The research team consisting of a scientist/astronomer, who was the Principal Investigator, and his scientist assistant were responsible for the content of the research program, the design and verification of all research equipment, the operation and maintenance of the flight experiment, and the reduction and analysis of the data. Problems at the aircraft-experiment interface were resolved with the Mission Manager of the Airborne Science Office, who was also responsible for all arrangements for aircraft operations, maintenance and logistics. While there was considerable overlap of duties between the two experimenters (based on extensive interchange of information in previous flight missions), the planning, target acquisition, and data analysis functions fell primarily to the Principal Investigator. The regular daily maintenance, preflight preparation and flight operation of the experiment were handled primarily by the scientist assistant. Functions such as troubleshooting, repair and optical alignment, that could cause delays in the flight schedule, were often worked together to effect the quickest solution. In most instances, the daily schedule had sufficient free time to permit experiment related activities to be pursued without undue pressure.

APPLICATION OF RESULTS TO SHUTTLE PROGRAM PLANNING AND DESIGN

Analysis of the data taken prior to and during the simulation mission indicates many areas of potential relevance for Shuttle/Sortie Lab mission planners. It should be recognized that due to the inherent differences between the constrained Lear mission and an actual Sortie Lab mission, caution must be exercised in deriving guidelines for Sortie Lab designers from the results of this first constrained Lear mission. It must also be borne in mind that these data reflect the attitudes, aptitudes, and previous experience, and the experimental equipment, of only one two-man team of experimenters, and may or may not be representative of other potential Shuttle users from the astronomy community.

With the above considerations in mind, the following statements may be made about the equipment, and the operational characteristics and preferences, of the experimenters who participated in this first Lear mission. The statements are grouped under headings identified prior to the mission as areas of interest to Sortie Lab design and planning personnel.

EXPERIMENTER CREW DUTY CYCLES

No constraints were placed on the two experimenters prior to the mission regarding minimum amounts of sleep. The experimenters were allowed to adapt to the nighttime flying and daytime sleeping regimen in any desired fashion. It was decided during the Airworthiness and Flight Safety Review Board meeting that the apparent fitness for flight of the experimenters would be subject to constant review by the Command Pilot who would cancel a mission anytime he felt the experimenters were not physically fit for flight. No questions relative to the experimenters' fitness actually arose during the course of the mission.

Under this condition of freedom in planning their personal schedules, the experimenters did not prepare a sleep/work schedule prior to the mission. They slept during time periods available between flights and maintenance activities, usually in periods not exceeding four or five hours. One experimenter slept a near normal total number of hours for the five-day period; the other slept less than half as much. The experimenters frequently did not sleep at the same time. Similarities and differences in the experimenters' schedules are related to the fact that during pre-flight and flight periods both individuals had a common goal (equipment preparation and operation), whereas, during times on the ground each had somewhat different responsibilities.

EXPERIMENTER CREW INTERACTION AND WORKLOAD DURING FLIGHT

Both experimenters were strapped into the double seat at the rear of the Lear cabin during takeoff and climbout, and during the final phases of the descent and landing. At all other times one experimenter sat on the aircraft floor immediately in front of the telescope, and the other sat on the step inside the crew entry hatch in position to operate the electronics rack. The experimenters were in almost constant voice communication with each other via the helmet-mounted microphones and earphones. While on-target, one experimenter was required full time to monitor/guide the telescope; the second was required full time to operate the recording equipment and telescope stabilization controls. There was no potential for unattended data taking, i.e., the equipment could not be operated in an unmanned mode. There was near zero potential for simultaneously operating other experiments, especially while on target. Any time spent operating or monitoring another experiment would have detracted from the experimenters' operation of their own equipment. In the Shuttle environment, where the times of approach and departure from target may be a smaller fraction of the total observation cycle, some potential

exists for the preparation and checkout of other experiments whose tracking and data acquisition systems have unmanned modes, or whose observation times alternate with the primary experiment.

EXPERIMENTER CREW/FLIGHT CREW COMMUNICATIONS AND DATA LINKS

The intercom loop in the Lear aircraft was modified for the ASSESS mission to permit the copilot/observer to switch into the experimenters' communication loop. The copilot remained on the experimenters' loop during the majority of each flight, except during take-off, climbout, approach, and landing. There was frequent, brief communication between the experimenters and copilot to establish such things as airspeed, altitude, outside air temperature, etc. The copilot monitored the experimenters' conversations fairly closely, and, thus, was immediately aware of any equipment problems, or experimenters' need for information or desires to deviate from the pre-planned track for that flight. This communication technique proved so beneficial to the experimenters that they recommended it for the normal communications mode for all ASO Lear astronomy missions. Extrapolating this arrangement to the Shuttle/Sortie Lab environment, it would seem useful to plan data displays for the experimenters so they are immediately aware of orbital or vehicle parameters affecting their observations (such as time till loss of target), or to include direct verbal participation in the experiment by a member of the flight crew.

When questioned about the potential usefulness of a data link on the Space Shuttle, the experimenters stated that such a link would be highly valuable for their type of experiment. In contrast to the alternative of on-board data processing, transmission of raw data to a ground station for processing and analysis would permit the experimenters to concentrate on data acquisition while in flight, rather than having to split their time between data acquisition and analysis. This judgement is apparently based on

the expectation of more frequent and numerous periods of observation, perhaps of significantly longer duration, as well as the advantage of more sophisticated data processing to suppress noise in signals from very weak sources. The telephone data link provided for this mission did not offer any of these advantages, and coupled with the fact that a limited quantity of data was involved, this mission did not address the usefulness of a data transmission link to any significant degree.

FLIGHT PLANNING

Flight planning prior to the mission was limited to establishing a list of targets and relative priorities. Targets for a specific flight were selected by the Principal Investigator within the 24-hour period immediately preceding each flight. Both experimenters emphasized that past experience has shown that more useful data is recorded during a typical series of airborne science flights if targets are selected on a day-by-day basis, thus, reflecting the accomplishments of all previous flights.

MONITORING OF EQUIPMENT STATUS

No automatic equipment was provided to monitor the status or performance of the experimental equipment during the flight. The intimate working relationship between the experimenters and their equipment assured immediate discovery of any equipment anomalies, and made it unnecessary to provide automatic monitoring equipment.

DATA RECORDING

Three means were employed to record data - a stereo cassette tape recorder, a single strip chart recorder, and a multi-channel digital printout. The recorder was started during the pre-flight activities and the entire flight and landing were recorded, with minor breaks when cassettes were changed. One channel was used to record all conversations between crewmen; the other recorded

experimental data. The single channel recorder ran continuously while the aircraft was on target, and produced about 60 ft. of printout per flight. The digital printout recorder was operated only at certain intervals while on track, and produced about 10 ft. of 4 in. wide paper for the series of seven flights.

SUPPORT EQUIPMENT

No restrictions were placed on the experimenters with respect to the weight or volume of tools and spares permitted. Although the experimenters were highly interested in minimizing the weight carried aboard the aircraft, most tools and spares were kept in the ground work trailer, where weights and volumes were not important. Under these conditions, the experimenters assembled large numbers of potentially useful items from the normal complement of tools and equipment available in the home laboratory and at Ames. No attempt was made on this first ASSESS mission to minimize the tool requirements or the required storage volume. Since no attempt was made to simulate the weight and volume restrictions of a Sortie Lab mission, the support equipment data taken are not strongly applicable to projected Sortie Lab missions, except to provide an early, one time, indication of the type of equipment these experimenters wanted. It is worth noting, however, that experimenters preparing for Sortie Lab missions can be expected to have maintained their equipment in the home laboratory with the usual miscellaneous assortment of tools and equipment, and any efforts required to standardize equipment and minimize tool requirements in preparation for a Sortie Lab mission will be reflected in terms of higher costs than those associated with an analogous Airborne Science mission.

VOLUME REQUIRED TO SUPPORT THE EXPERIMENT

The simulation of realistic living/working space and accommodations was not one of the guidelines of the first Lear mission.

Nevertheless, some general comments can be made to illustrate utilization of the space available in the aircraft, and that provided in the trailers. The approximate sizes were: aircraft cabin volume 150 cubic ft., work space in trailer 1000 cubic ft. (nominal), living space in trailer 1300 cubic ft. for crew of four. The aircraft cabin was crowded; within the 150 cubic ft. of volume each experimenter and his portion of the experiment equipment occupied an area of about 3 by 4 ft. The remaining area of about 2 by 4 ft. held the seats used by the experimenters during take-off and landing. The experimenters sat on the aircraft floor at all other times, facing their equipment; special care was necessary to keep equipment cabling from interfering with normal movement.

The work space and working environment within the aircraft represent very minimum values required to support the three-hour missions. It must be recognized, however, that the telescope installation in the Lear Jet is arranged, as a matter of convenience, through an existing opening normally occupied by a window. If the vehicle were designed to accommodate experiments such as a telescope, as will be the case in the Sortie Lab, the limited space available could probably have been more efficiently utilized.

Within the work trailer an area of 140 sq. ft. was allotted for the experimenters' use, including ample walking space. Furnishings were standard office and shop equipment (no attempt was made to miniaturize) as shown in Figure 5. The space was stated to be more than adequate for the few maintenance activities that were required; since no major equipment failures occurred, the area was never fully utilized. In summary, this experiment, which requires nearly the full time attention of two experimenters, could be accommodated in perhaps less than half the volume available in the Sortie Lab.

The living space was adequate, functionally, but perhaps too small for the long time comfort of this untrained (in the confinement sense) group. As mentioned earlier, it was not often that all four were sleeping, or even in the living quarters, at the same time, since work schedules were not coincident and considerable waking time was spent in the work area. Under these conditions the living space was adequate; however, one crew member stated that it would be "pretty small" for extended use by four people.

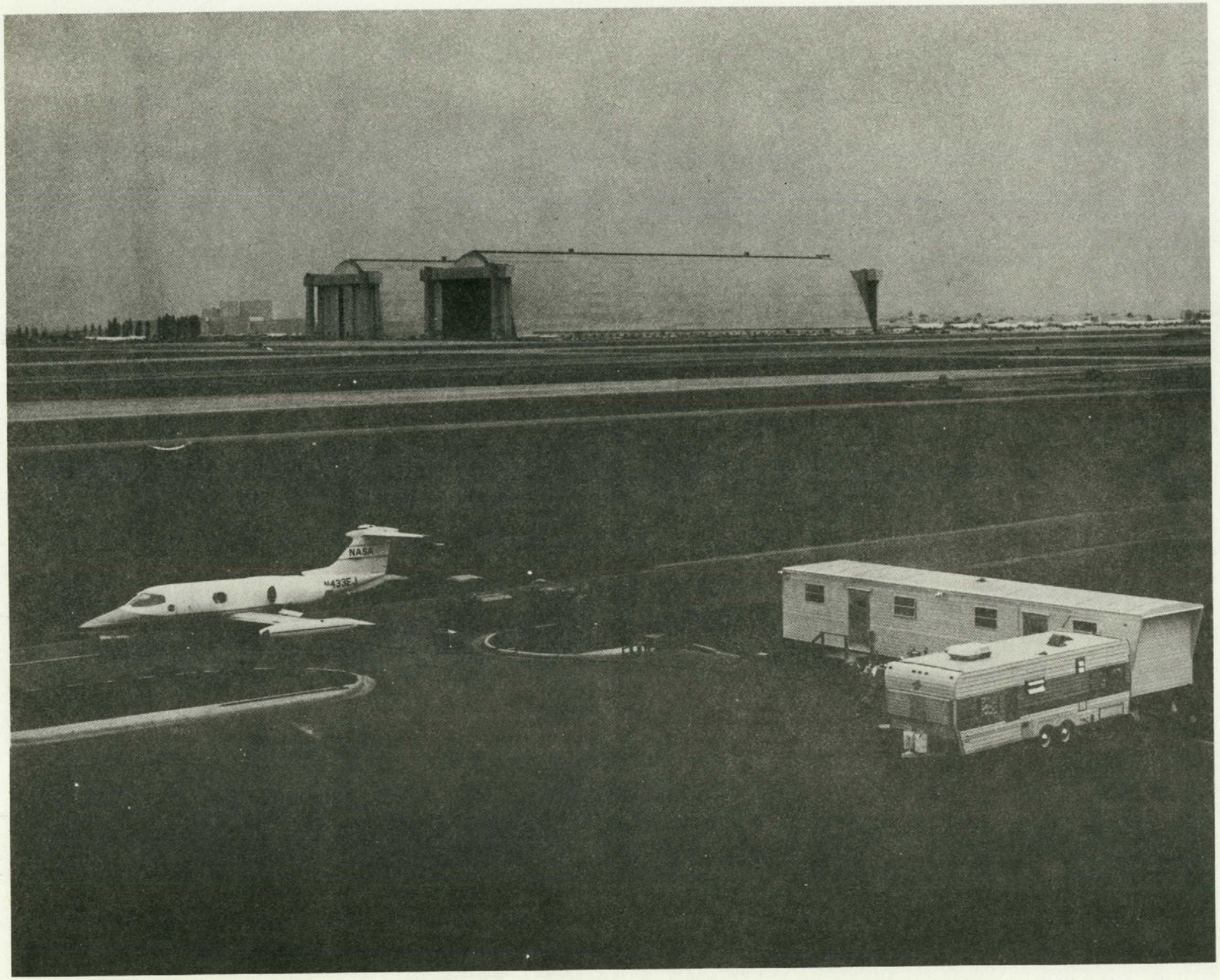

Figure 1. - View of simulation site.

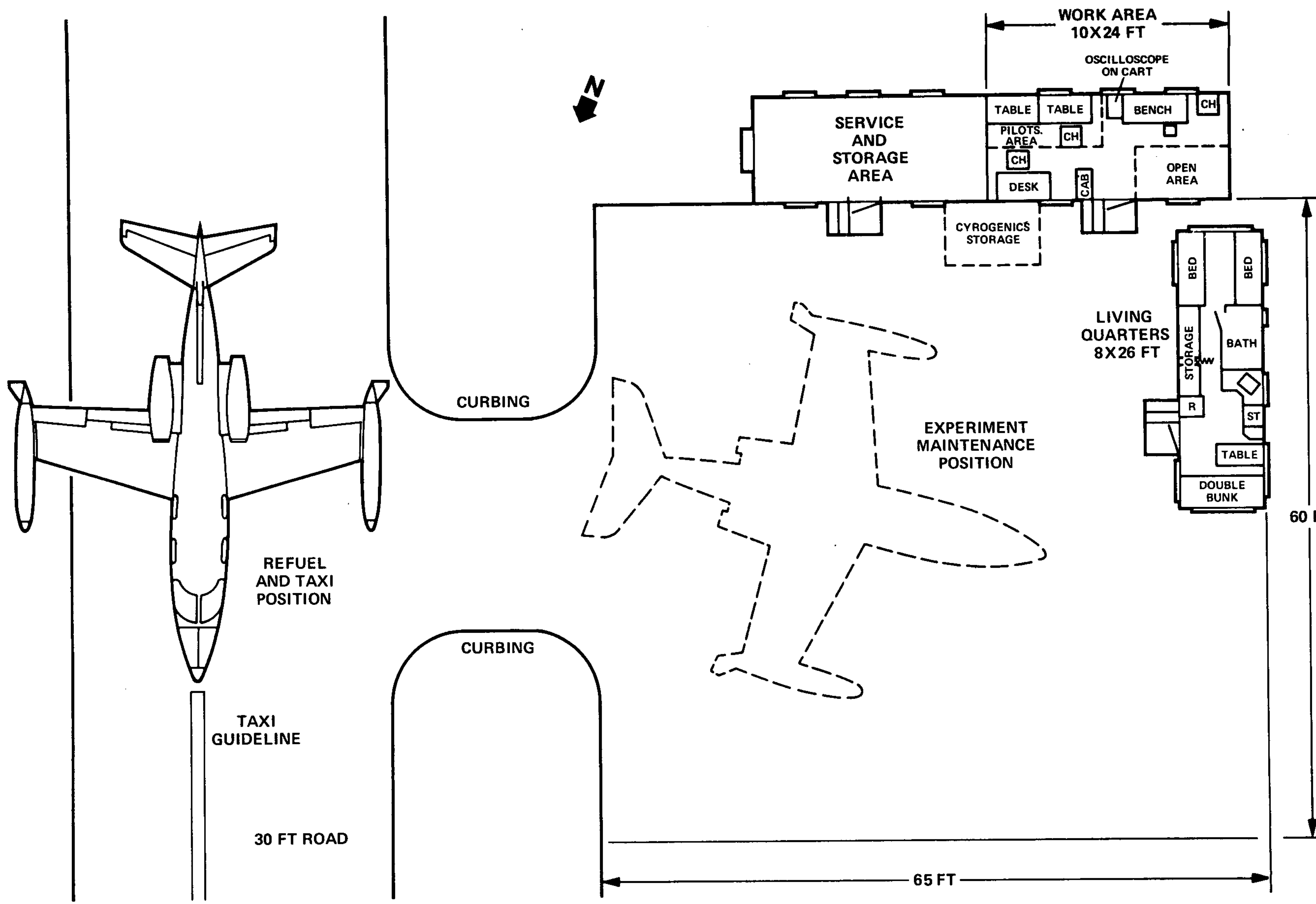

Figure 2.—Arrangement of the simulation complex.

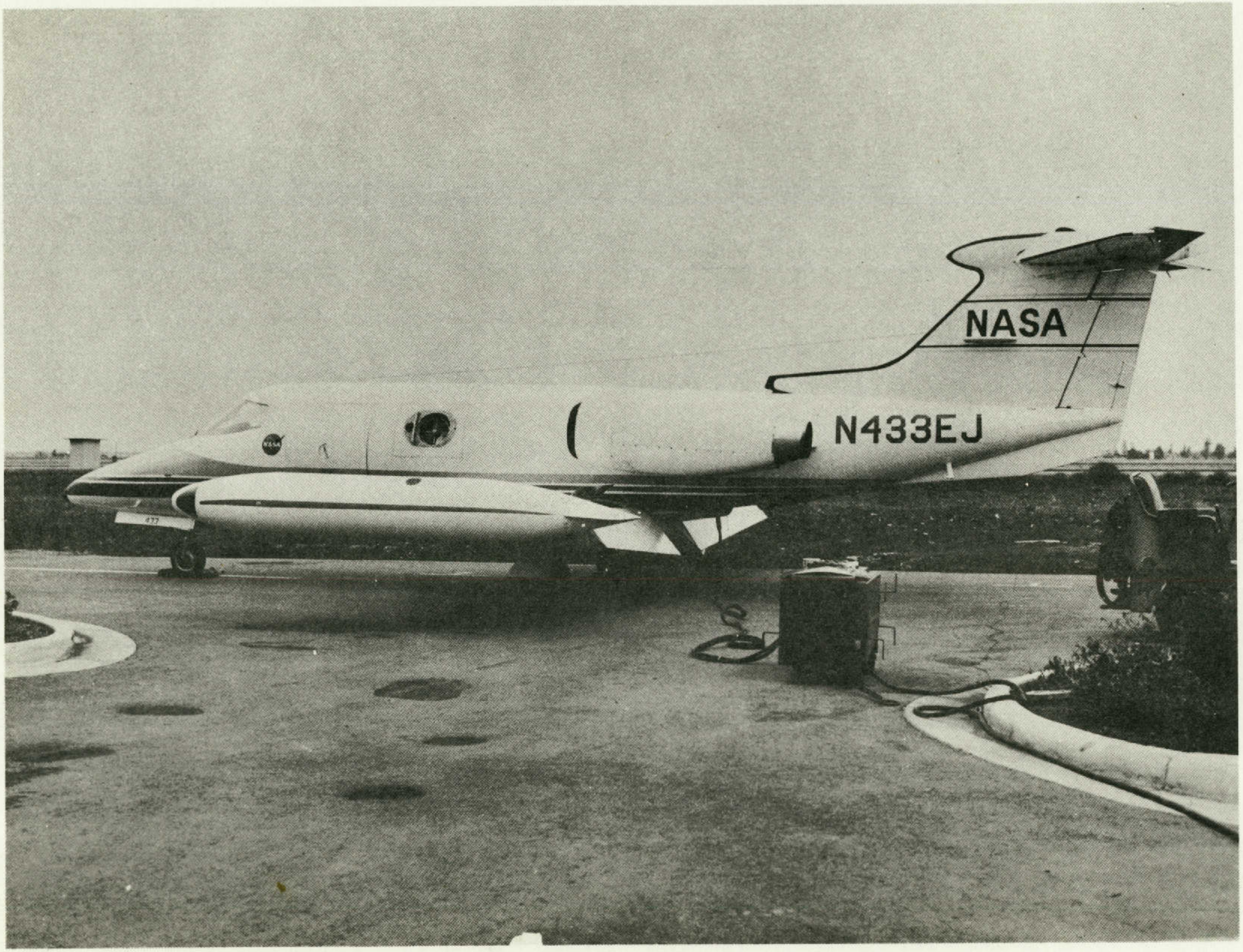

Figure 3. - ASSESS mission Lear aircraft.

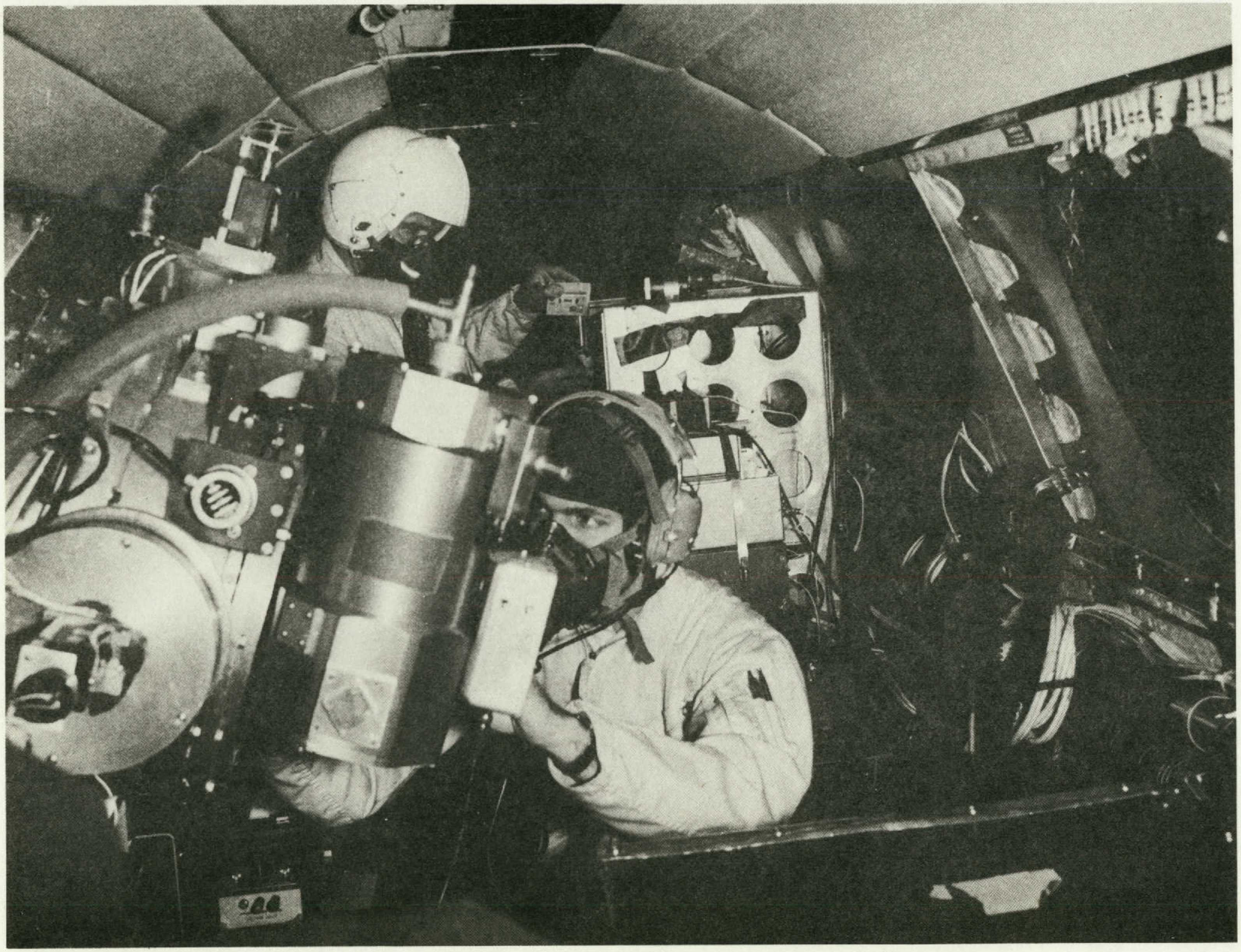

Figure 4.-General view of aircraft cabin, looking forward.

Figure 5. - General view of work area.

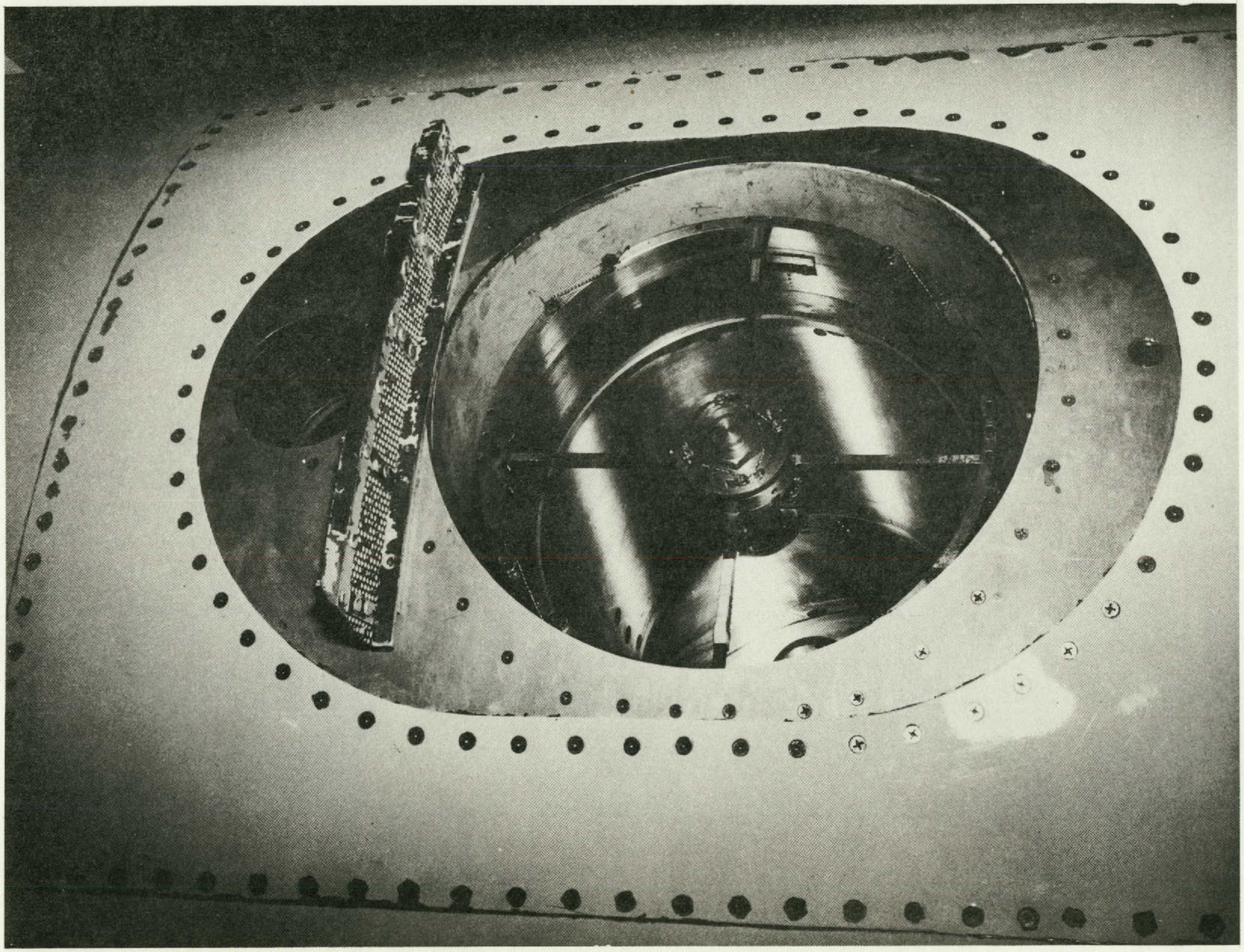

Figure 6. - External view of telescope port on aircraft.

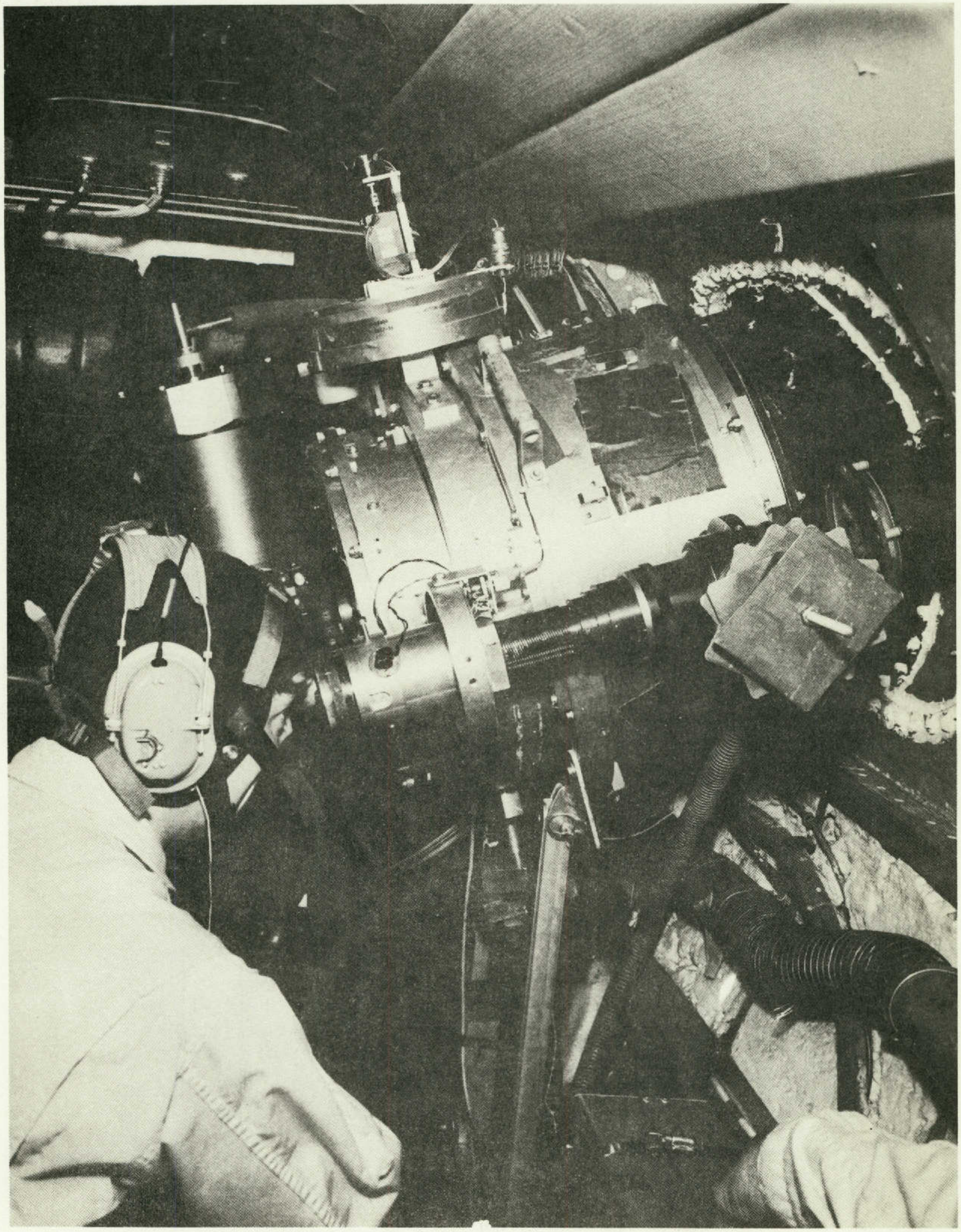

Figure 7. - Telescope in aircraft cabin.

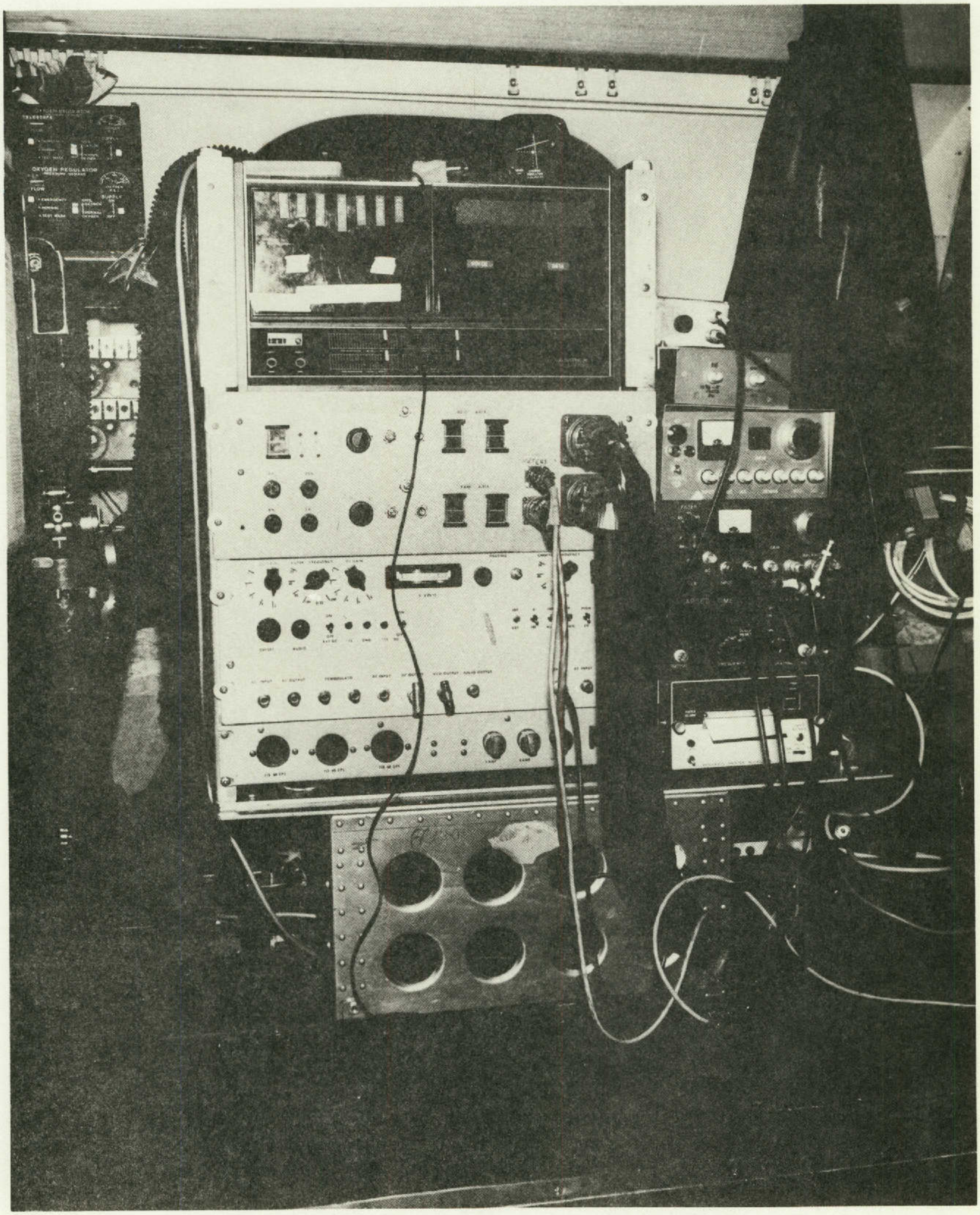

Figure 8.-Telescope electronics panel.

COMPONENT	SOURCE	ESTIMATED POWER DEMAND
TELESCOPE		
• CHOPPER AND SECONDARY MIRROR ASSEMBLY	CUSTOM – EXPERIMENTER	3 AMPS – 28 VDC
• PRIMARY MIRROR	CUSTOM – EXPERIMENTER	—
• TELESCOPE STRUCTURE	CUSTOM – EXPERIMENTER	—
• OPTICAL DEWAR	CUSTOM – COMMERCIAL	—
• DETECTOR (IR)	CUSTOM – COMMERCIAL	
• STABILIZATION SYSTEM	CUSTOM – EXPERIMENTER	40 AMPS – 28 VDC (MAX)
ELECTRONICS		
• LOW NOISE PRE-AMPLIFIER	OFF-THE-SHELF	9 VOLT TRANSISTOR BATTERY
• SIGNAL CHANNEL ELECTRONICS	CUSTOM – EXPERIMENTER	1 AMP – 28 VDC
• CHOPPER DRIVER AND PHASE REFERENCE	CUSTOM – EXPERIMENTER	
• INVERTERS (SUPPLY OSCILLOSCOPE AND RECORDERS)	OFF-THE-SHELF	
RECORDERS		4 AMPS – 28 VDC
• MAGNETIC TAPE RECORDER (115V-60Hz)	OFF-THE-SHELF	
• STRIP CHART RECORDERS (115V-60Hz)	OFF-THE-SHELF	
ACCESSORIES		
• VACUUM PUMP AND MOTOR	OFF-THE-SHELF	12 AMPS – 28 VDC
• OSCILLOSCOPE (115V-60Hz)	OFF-THE-SHELF	1 AMP – 28 VDC
	TOTAL	61 AMPS – 28 VDC(1)

NOTES: (1) Measured load was 62 Amps – 28 VDC.

Figure 9.—Experiment components.

ITEM	SIZE (INCHES)	SUPPLIED BY	EXPMTR. REQUEST	USED
WORK BENCH AND STOOL	34x72;	ARC	NO	YES
STORAGE CABINET	36x18x76			
DESK	34x60			
WORK TABLES (2) (FOR PILOTS)	34x60			
CHAIRS (3)	—			
BLACKBOARD	48x72			
BULLETIN BOARD	36x72			
FIRE EXTINGUISHER	—			NO
FIRST AID KIT	2x6x10			NO
DESK LAMP	—		YES	YES
TELEPHONE & FTS DIRECTORY	—		NO	
TYPEWRITER	—		YES	
CLOCK	—	EXPMTR.		YES
35mm. CAMERA & STROBE LIGHT	—	"		NO
TOTAL = 18 ITEMS				TOTAL USED = 15 (83%)

Part A – Furnishings.

Figure 10.–Inventory of support equipment in the work area

ITEM	SIZE AND WEIGHT	SUPPLIED BY	EXPMTR. REQUEST	USED
EXPERIMENTERS TOOL SUPPLY				
GREEN TOOL KIT	2x7x19, 18 lb.	EXPMTR.		YES
GRAY TOOL BOX	8x9x14, 12 lb.			NO
BROWN TOOL KIT	9x13x20, 40 lb.			YES
END WRENCH SET (10)	INCLUDED IN WEIGHTS SHOWN ABOVE FOR GREEN AND BROWN TOOL KITS	EXPMTR.		YES (3)
BOX WRENCH SET (8)				YES (2)
SCREW DRIVERS (8)				YES (4)
JEWELERS SCREW DRIVERS (10)				YES (1)
PLIERS (2)				YES (2)
SMALL FILES (5)				YES (2)
HACKSAW				NO
BALLPEEN HAMMER				
SOCKET SET (3/16" – 1/2") (6)				
RACHET AND EXTENSION (2)				
ASSORTED TAPS (10)				
KNIFE BLADES (8)				
TWEEZERS (2)				YES (1)
SOLDERING IRON, 45W				YES
1-1/2" C CLAMPS (2)				NO
MAGNIFYING LENS				YES
FEELER GAGE, SECONDARY MIRROR (2" DIA.)				NO
1/4" ELECTRIC DRILL		ARC	YES	YES
DRILL BIT SET (#1–60) (20)				YES (1)
DRILL BIT SET (1/16–1/2) (8)				YES (1)
SOCKET SET (1/8–1/2) (6)				NO
PROPANE TORCH				NO
TOTAL = 114 ITEMS				TOTAL USED = 20 (18%)

*Some tool quantities are estimated, but quantities identified cover essentially all tools used.

Part B – Hand tools*
Figure 10 – continued

ITEM	SIZE AND WEIGHT	SUPPLIED BY	EXPMTR. REQUEST	USED
HIGH-SPEED RECORDER (STRIP CHART)	4½x4x13½, 9 lb.	EXPMTR.		NO
PRECISION POTENTIOMETER	2x3x5, ½ lb.			NO
VOLT-OHM METER (POCKET SIZE)	–			YES
DIGITAL VOLTMETER (0–9.999V)	4x17x17, 20 lb.	ARC	YES	
POWER SUPPLY (TO 50V & 5A DC)	5x15x19, 53 lb.			
INVERTER (100VA DC to 400Hz AC)	4x5x9, 5 lb.			NO
FUNCTION GENERATOR	5x8x8, 6 lb.			
RMS VOLTMETER (320μV-320V)	10x12x14, 20 lb.			
ELECTRONIC COUNTER	5x17x18, 37 lb.			
VOLT-OHM METER	3x6x8, 3 lb.			
DUAL BEAM OSCILLOSCOPE	18x30x52, 154 lb.			
OSCILLOSCOPE PREAMPS (3)	6x7x10, 6 lb.(3)			
SCOPE CAMERA AND MOUNT	–		NO	
CASSETTE TAPE RECORDER	3x11x14, 6 lb.	EXPMTR.		YES
AUDIO AMPLIFIER	3x6x8, 2 lb.	EXPMTR.		YES
VACUUM PUMP	10x12x14, 40 lb.	ARC	YES	NO
LIGHT SOURCE, VARIABLE INTENSITY	1½x1½x8, 1 lb.	EXPMTR.		
EXTENSION LIGHT, BATTERY OPER.				
CYROGEN GLOVES				YES
MISC. CLIP LEADS				YES
LEAD BALANCE WEIGHTS				YES
TOTAL = 23 ITEMS				TOTAL USED = 8 (35%)
BOOKS AND MANUALS				
TECHNOLOGY OF LIQUID HELIUM		EXPMTR.		NO
CYROGENIC ENGINEERING				
HANDBOOK OF MILITARY INFRA-RED TECHNOLOGY				
TABLES AND FORMULA (PAMPHLET)				
INDUSTRIAL GAS DATA (PAMPHLET)				
CIRCUIT DIAGRAMS FOR FLIGHT ELECTRONICS (BOUND)				
CHART RECORDER (MANUAL)				
CASSETTE TAPE DECK (MANUAL)				
DRAWINGS AND CIRCUIT DIAGRAMS				
STABILIZATION CONTROL SCHEMATIC FOR IR TELESCOPE				
LEAR CABIN LAYOUT DWG.		ARC	YES	
TOTAL = 10 ITEMS				NONE USED

Part C – Electronic and other maintenance equipment, reference material.

Figure 10 – continued

ITEM	SIZE AND WEIGHT	SUPPLIED BY	EXPMTR. REQUEST	USED
OSCILLOSCOPE (MINIATURE)	3x5x9, 3 lb.	EXPMTR.		NO
REGULATED POWER SUPPLY (30V, 10A)	4x5x11, 5 lb.			NO
PHASE-LOCK AMPLIFIER (2)	—			YES (ONE)
FREQUENCY TO VOLTAGE CONVERTER	4x5x18, 5 lb.			NO
STRIP CHART RECORDER	6x10x15, 9 lb.			
REGULATED POWER SUPPLY (SEMI-COND.)	2x3x4, 1 lb.			
POWER SUPPLY (2A, 5V DC)	3x4x5, 2 lb.			
DC SERVO-AMPLIFIER	1x2x3½, ½ lb.			
SOLENOIDS (8) (2 BOXES)	2x4x6, 1¼ lb.	EXPMTR.		NO
SIGNAL AND POWER TRANSISTORS (1 BOX)	1x4x6, 1 lb.			
TRANSISTORS AND INTEGR. CIRCUITS (1 BOX)	1x5x6, ½ lb.			
RESISTORS, CAPACITORS, MISC. (4 BOXES)	—— 1½ lb.			
DEWAR PARTS		EXPMTR.		NO
BEAM-SPLITTER MIRROR				
TELESCOPE PARTS (15 SMALL BAGS AND BOXES)				
STRIP CHART PENS (2)				
TOTAL = 35 ITEMS				TOTAL USED = 1 (3%)

Part D – Spare units and parts.
Figure 10 – continued

ITEM	SIZE AND WEIGHT	SUPPLIED BY	EXPMTR. REQUEST	USED
BATTERIES (7½V) (24)	6x6x11, 14 lb.	EXPMTR.		NO
BATTERIES (22½V) (6)	3x4x10, 3 lb.			YES
BATTERIES (1½V) (16) PENLITE	1x4x10, 1 lb.			
BATTERIES (1½V) (26) STD. SIZE	6x4x7, 5 lb.			
FUSES (8 BOXES)	1½x1½x3, ¼ lb.			NO
TAPE CASSETTES (36)	6x6x8, 3 lb.	ARC		16
RECORDER PAPER (15 ROLLS)	—	EXPMTR.		8
LIQUID HELIUM, 2 DEWARS	50 liters	ARC	YES	30 liters
LIQUID NITROGEN, 1 DEWAR	50 liters			20 liters
HELIUM GAS, HIGH PRES. BOTTLE	250 scf			NO
NITROGEN GAS, HIGH PRES. BOTTLE	250 scf			
TOLUENE	8 pints			
DISTILLED WATER	1 gal			
ALCOHOL (200 PROOF)	2 pints	EXPMTR		YES
VACUUM PUMP OIL	2/3 pint			NO
VARNISH (VACUUM SEAL)	50 ml.			
HIGH-VACUUM SEALANT	—			
SILICONE VACUUM GREASE	1 TUBE			YES
SILICONE RUBBER ADHESIVES	2 TUBES			NO
PLASTIC CEMENT	1 TUBE			NO
RTV ADHESIVE/SEALANT	1 TUBE			YES
EPOXY ADHESIVE	2 BAGS			NO
SILICONE HEAT SINK COMPOUND	1 TUBE			
SPRAY PAINT, FLAT BLACK	1 CAN, 8 oz.			
PLASTIC TAPE (2 ROLLS)	—			
VACUUM HOSE (½ ID)	—			NO
COPPER TUBING (½ OD)	4 ft.			NO
SOLDER WIRE	4 ft.			YES
CLOTH INSULATED WIRE (1 ROLL)	—			NO
Ni-Cr-Fe ALLOY WIRE (1 ROLL)	—			NO
RUBBER STOPPER (DEWAR)	—			YES
RUBBER BALLOONS (DEWAR)	—			YES
WASH BOTTLE	1 pint			NO
COTTON SWABS (100)		ARC	YES	YES
GAUZE SPONGES (200)				NO
PAPER TOWELS (NO LINT)				YES
ALUMINUM FOIL (24 INCH)	1 ROLL	EXPMTR		NO
WHITE POSTER BOARD (1 SHEET)	30x40	EXPMTR		NO
RUBBER BANDS (1 BOX)		ARC	YES	YES
TOTAL = 39 ITEMS				TOTAL USED = 17 (44%)

Part E – Expendable supplies.
Figure 10 – continued

ITEM	SIZE AND WEIGHT	SUPPLIED BY	EXPMTR. REQUEST	USED
ELECTRONIC POCKET CALCULATOR		EXPMTR.		YES
SLIDE RULES (2)				YES
BOOKS				
NORTON STAR ATLAS				NO
MONTHLY MEAN AEROLOGICAL CROSS SECTIONS (BOOKLET)				
AMERICAN EPHEMERIS AND NAUTICAL ALMANAC, 1972		ARC	YES	YES
AIR ALMANAC, SEPT. TO DEC., 1972				NO
ASTROPHYSICAL QUANTITIES (ALLEN)				NO
AMERICAN COLLEGE DICTIONARY		EXPMTR.		YES
REFERENCE NOTEBOOKS (3)	9x12x2½	EXPMTR.		YES
REFERENCE REPORTS, IR ASTRON. (5)				NO
JOURNAL ARTICLES, IR ASTRON. (7)				
ASTROPHYSICAL JOURNAL (5 COPIES)				
LEAR AND CV 990 SCHEDULES		ARC	YES	
ASO RESEARCH MGT. FLOW CHART		ARC		
DRAFTING INSTRUMENTS (4)		EXPMTR.		YES
SUPPLIES				
GRAPH PAPER		EXPMTR.		YES
TYPING PAPER, ENVELOPES		ARC		NO
CARBON PAPER		ARC		
3x5 CARDS		EXPMTR.		
PENCILS, ERASERS, SCISSORS		ARC		YES
TOTAL = 39 ITEMS				TOTAL USED = 10 (26%)

Part F – Materials for flight planning and data reduction.

Figure 10 – concluded

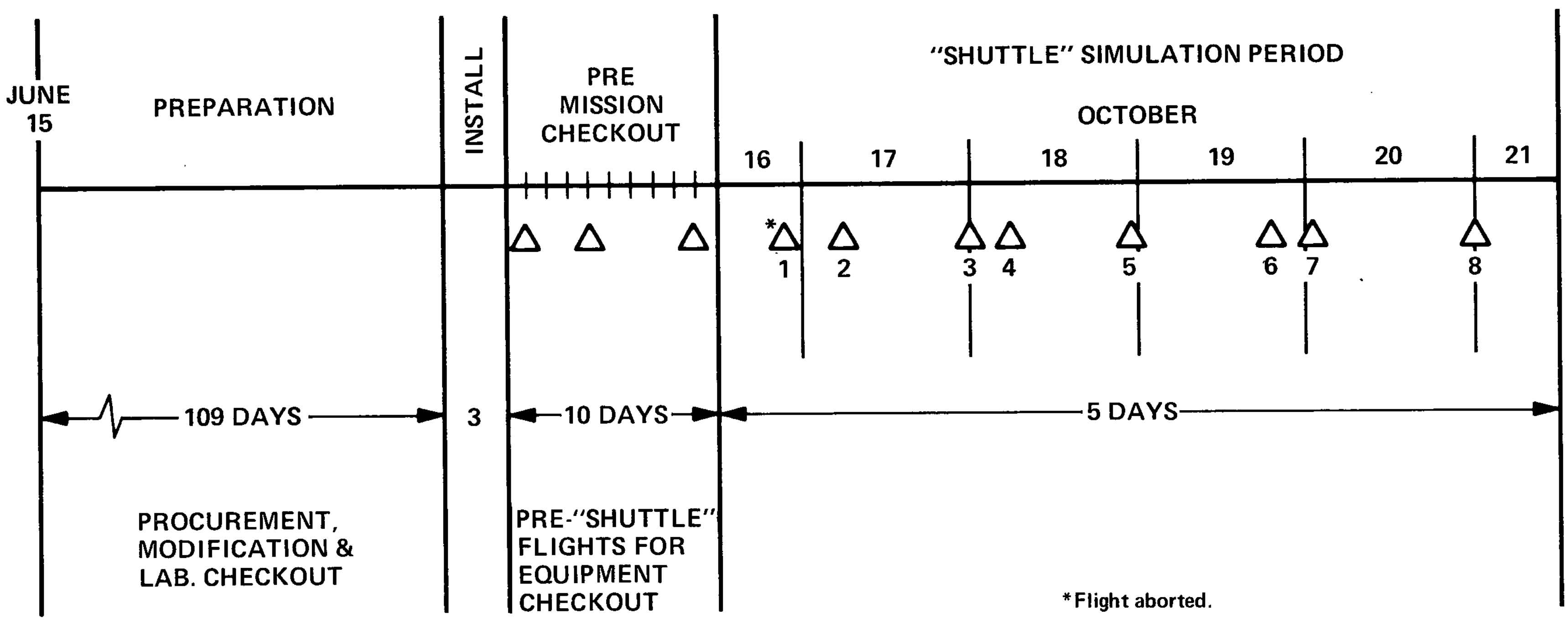

Figure 11.–Mission timeline.

COMPONENT	EXTENT OF CHECK-OUT	TYPE OF TEST	TEST EQUIPMENT USED	PROBLEM HIGHLIGHTS
TELESCOPE HELIUM DEWAR[1] (FLIGHT)	MEASUREMENT OF HELIUM LOSS[3]	OPERATIONAL	FLOW METER	NONE
HELIUM DEWAR[2] (BACK-UP)	MEASUREMENT OF HELIUM LOSS	OPERATIONAL	FLOW METER	PRE-EXISTING LEAK REPAIRED
DETECTOR[1]	TESTED SEPARATELY FOR OUTPUT NOISE AND MICROPHONICS[3]	OPERATIONAL	STANDARD DEWAR PRE-AMPLIFIER, AND OSCILLOSCOPE	NONE
DEWAR AND DETECTOR[1]	TESTED AS COMPLETE CRYOGENIC-OPTICAL SYSTEM FOR BEAM PATTERN, DETECTOR NOISE, AND OUTPUT RESPONSE[3]	OPERATIONAL	OSCILLOSCOPE	NONE
COMPLETE TELESCOPE	NONE	—	—	—
STABILIZATION SYSTEM	TEST OF DYNAMIC RESPONSE	OPERATIONAL	BUBBLE LEVEL FOR ZEROING AND GUIDE TELESCOPE ON STAR	NONE

[1]New unit for simulation mission.

[2]Existing unit used in previous flights.

[3]Tested at contractor's laboratory.

Part A – Telescope and detector

Figure 12.–Tests of experiment in the laboratory.

COMPONENT	EXTENT OF CHECK-OUT	TYPE OF TEST	TEST EQUIPMENT USED	PROBLEM HIGHLIGHTS
ELECTRONICS				
PRE-AMPLIFIER	TESTED SEPARATELY FOR GAIN AND NOISE	OPERATIONAL	SQUARE-WAVE GENERATOR AND OSCILLOSCOPE	NONE
SIGNAL CHANNEL ELECTRONICS	TESTED SEPARATELY TO CHECK GAIN AND BATTERY CONDITION	OPERATIONAL	BUILT-IN METERS	NONE
CHOPPER DRIVER AND PHASE REFERENCE	CHOPPER VOLTAGE MEASURED	OPERATIONAL	OSCILLOSCOPE	NONE
RECORDERS				
MAGNETIC-TAPE RECORDER	RECORDER OPERATED	OPERATIONAL	PRE-RECORDED CASSETTE	NONE
STRIP-CHART RECORDER	RECORDER OPERATED	OPERATIONAL	NONE	NONE
ACCESSORIES				
VACUUM PUMP AND MOTOR	NONE	—	—	—
OSCILLOSCOPE	USED IN TESTING OTHER EQUIPMENT	OPERATIONAL	NONE	NONE
INVERTER	NONE	—	—	—

Part B – Electronics, recorders and accessories.
Figure 12 – concluded

PROBLEM	SYMPTOM	WHEN DETECTED	HOW FIXED	COMMENTS
DEWAR	OVER-PRESSURIZATION	DURING "ENVIRONMENTAL" CHECK-OUT FLIGHTS	RE-BUILT	DELAYED MISSION 5 DAYS
INTEGRATED CIRCUIT	INTERMITTENT DE-TECTOR RESPONSE	DURING "ENVIRONMENTAL" CHECK-OUT FLIGHTS	REPLACED	NO DELAY
PINCHED VACUUM HOSE	LOW PUMP-DOWN RATE	DURING "SHUTTLE" MISSION	RE-POSITIONED HOSE	ABORTED FLIGHT
STABILIZATION GYRO	POOR TELESCOPE POINTING CONTROL	DURING "SHUTTLE" MISSION	RE-ALIGNED GYRO	IMPROVED DATA RETURN

Figure 13.–Experiment problems.

ITEM	NO. SUPPLIED	NO. USED	% USED
HAND TOOLS	114	20	18
TEST EQUIPMENT	23	8	35
SPARE PARTS	35	1	3
EXPENDABLE SUPPLIES	39	17	44
FLIGHT PLANNING REFERENCE MATERIAL	39	10	26

Figure 14.—Utilization of support equipment.

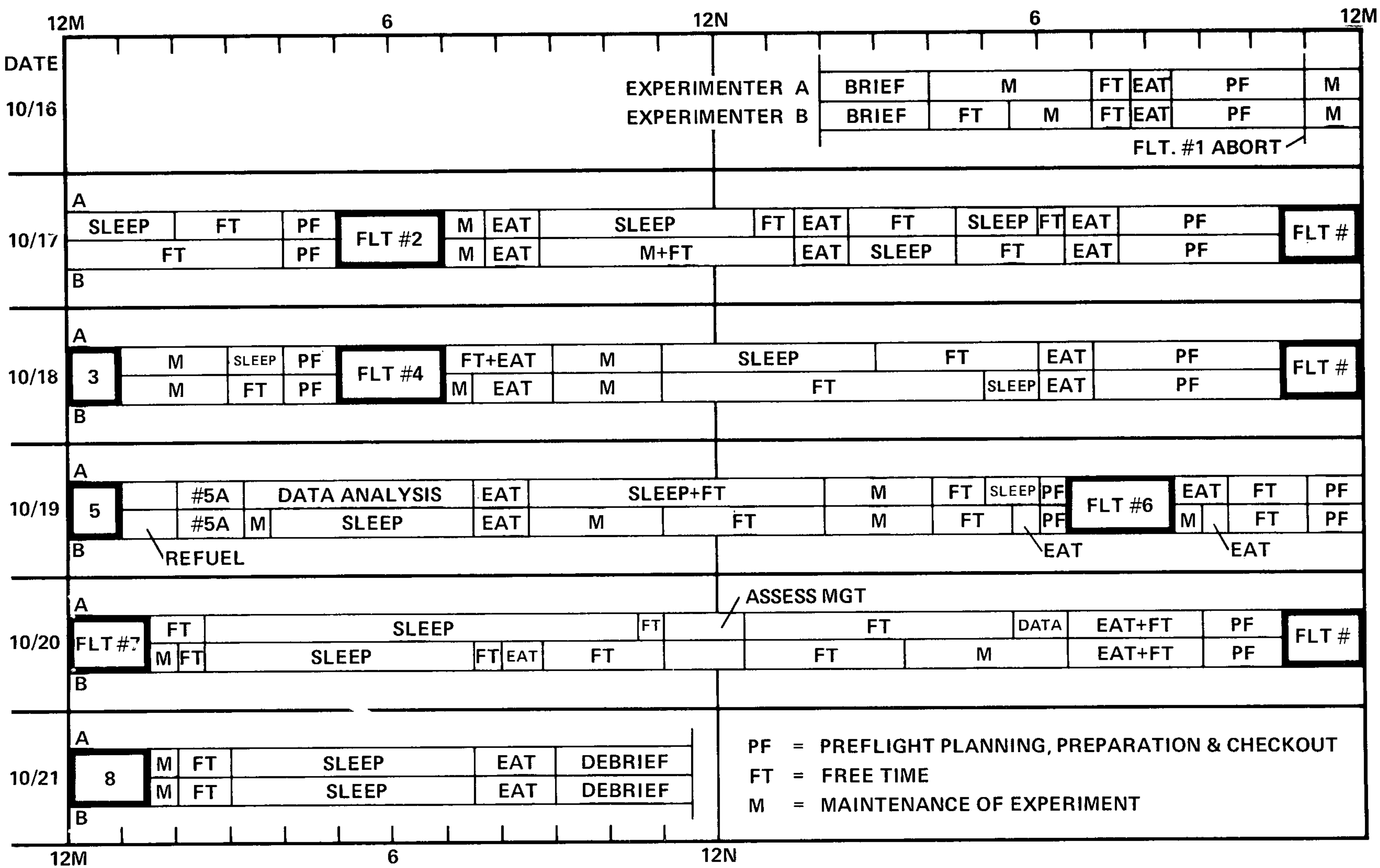

Figure 15.–Experimenters' timelines.

MISSION PHASE	MISSION ELEMENT	TIME SPENT BY TWO EXPERIMENTERS, MAN-MINUTES PER FLIGHT									
			FLT #1	FLT #2	FLT #3	FLT #4	FLT #5	FLT #6	FLT #7	FLT #8	AVG. PER FLIGHT
		10/16/72	10/16/72	10/17/72	10/17/72	10/18/72	10/18/72	10/19/72	10/20/72	10/20/72	
			–	0500	2235	0500	2230	1825	0010	2230	
PRE-FLIGHT	EQUIP. MAINT.		120	–	–	–	35	–	–	–	–
	FLIGHT PREP.		300	90	305	105	500	55	70	150	197
IN-FLIGHT	TAXI AND TAKEOFF		FLIGHT ABORTED	27	29	42	12	28	30	30	28
	EXPER. PREP.			60	112	62	80	68	70	70	75
	OBSERVATION			120	32	48	126	78	26	124	79
	BETWEEN OBSV.			0	30	5	50	$0^{(2)}$	36	80	40
	MAINTENANCE			–	56	54	–	–	72	10	48
	DESCEND AND LAND			46	52	68	66	100	50	40	60
POST-FLIGHT	REFUEL LAYOVER			0	0	0	284	0	0	0	–
	UNLOAD AND MAINT.			30	30	30	30	30	30	30	30
BETWEEN FLIGHTS	MAINT. AND REPAIR		180	60	235	240	300	0	210	–	175
	SLEEPING		120	450	60	240	570	0	750	540	–
	FREE TIME	480	360	780	60	960	570	305	1020	300	–
	DATA REDUCT.	0	–	–	–	–	210	–	60	–	–
	ASSESS PHOTOS	0	0	0	0	0	0	0	140	0	–

Figure 16.–Mission time elements.

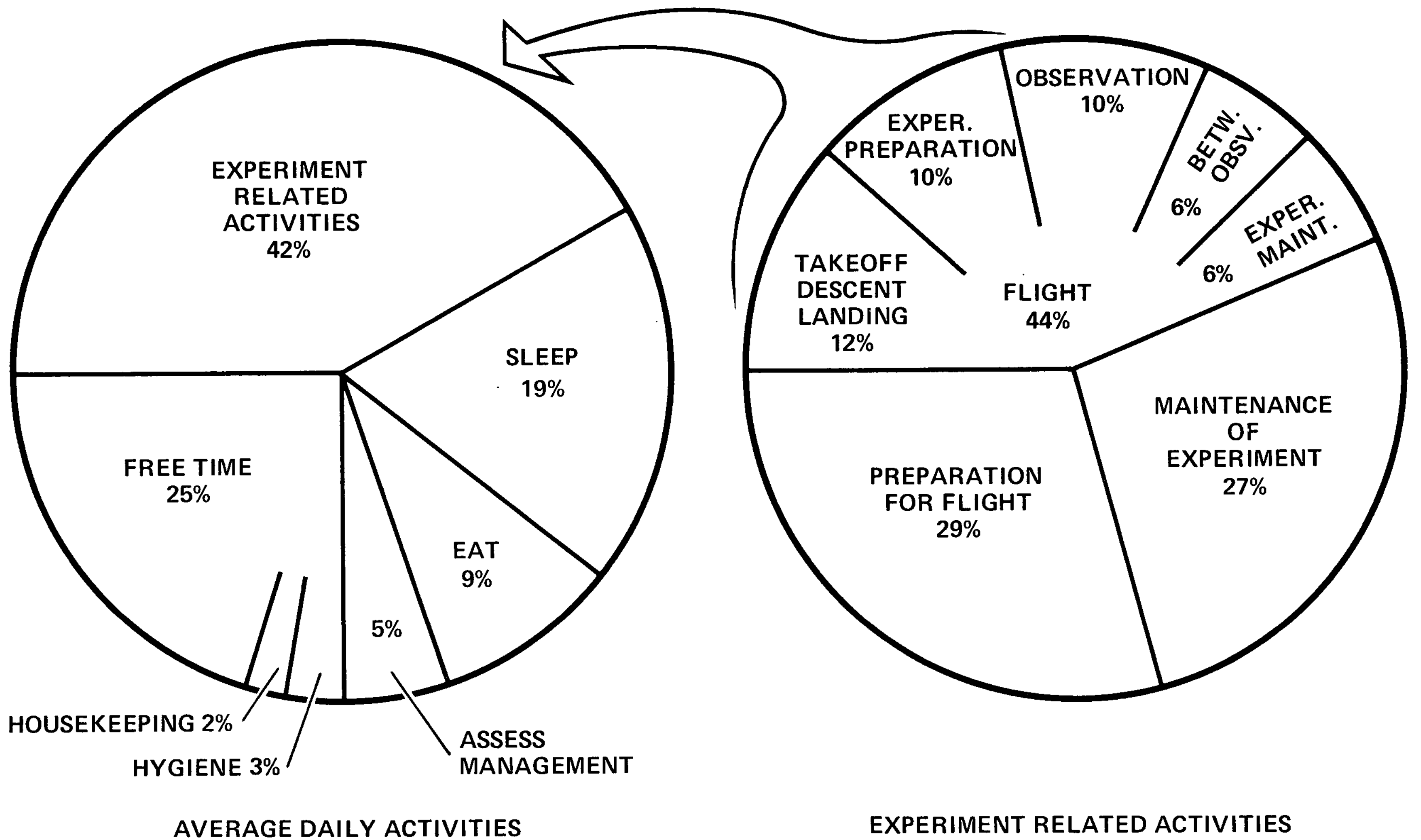

Figure 17.–Experimenters' activity chart.

PREFLIGHT TIMELINE (TYPICAL)

T – 110 MIN.	TOP-OFF BOTH DEWARS WITH FRESH CYROGENICS.
T – 80 MIN.	MOVE DEWAR TO AIRCRAFT, START VACUUM PUMP AND ADJUST VALVES TO CONTROL EVACUATION RATE. TURN ON TELESCOPE POWER TO ALLOW GYRO WARMUP TO FULL TEMPERATURE EQUILIBRIUM.
T – 65 MIN.	CHECK PROGRESS OF DEWAR PUMPDOWN ONE OR MORE TIMES.
T – 45 MIN.	TURN ON ALL ELECTRONICS, ALLOW 10 MINUTE WARMUP.
T – 35 MIN.	CHECK DETECTOR OPERATION WITH "HAND SIGNAL" PAST TELESCOPE PORT IN FUSELAGE, READ STRIP CHART RECORDER.
T – 30 MIN.	FINAL LOADING OF SUPPLIES
T – 20 MIN.	DOOR CLOSES.
T = 0	TAKE OFF.

POSTFLIGHT TIMELINE (TYPICAL)

L = 0	LANDING
L + 10 MIN.	TAXI TO SITE AND SECURE AIRCRAFT.
L + 25 MIN.	TOP-OFF BACK-UP DEWAR AND INSTALL IN AIRCRAFT; REMOVE AND EMPTY NEW DEWAR; START VACUUM PUMP AND SET VALVES.
OR	TOP-OFF NEW DEWAR WITH LN_2 WHILE IN AIRCRAFT; KEEP VACUUM PUMP OPERATING BETWEEN FLIGHTS.
OR	AFTER SECOND FLIGHT, SHUT DOWN VACUUM PUMP AND EMPTY DEWAR.
L + 35 MIN.	POWER TO ELECTRONICS TURNED OFF, TELESCOPE POWER LEFT ON BETWEEN FLIGHTS.
OR	ALL POWER OFF AFTER SECOND FLIGHT.
	REMOVE STRIP CHART RECORD AND TAPE RECORDER CASSETTES.

Figure 18.–Preflight and postflight experiment workflows.

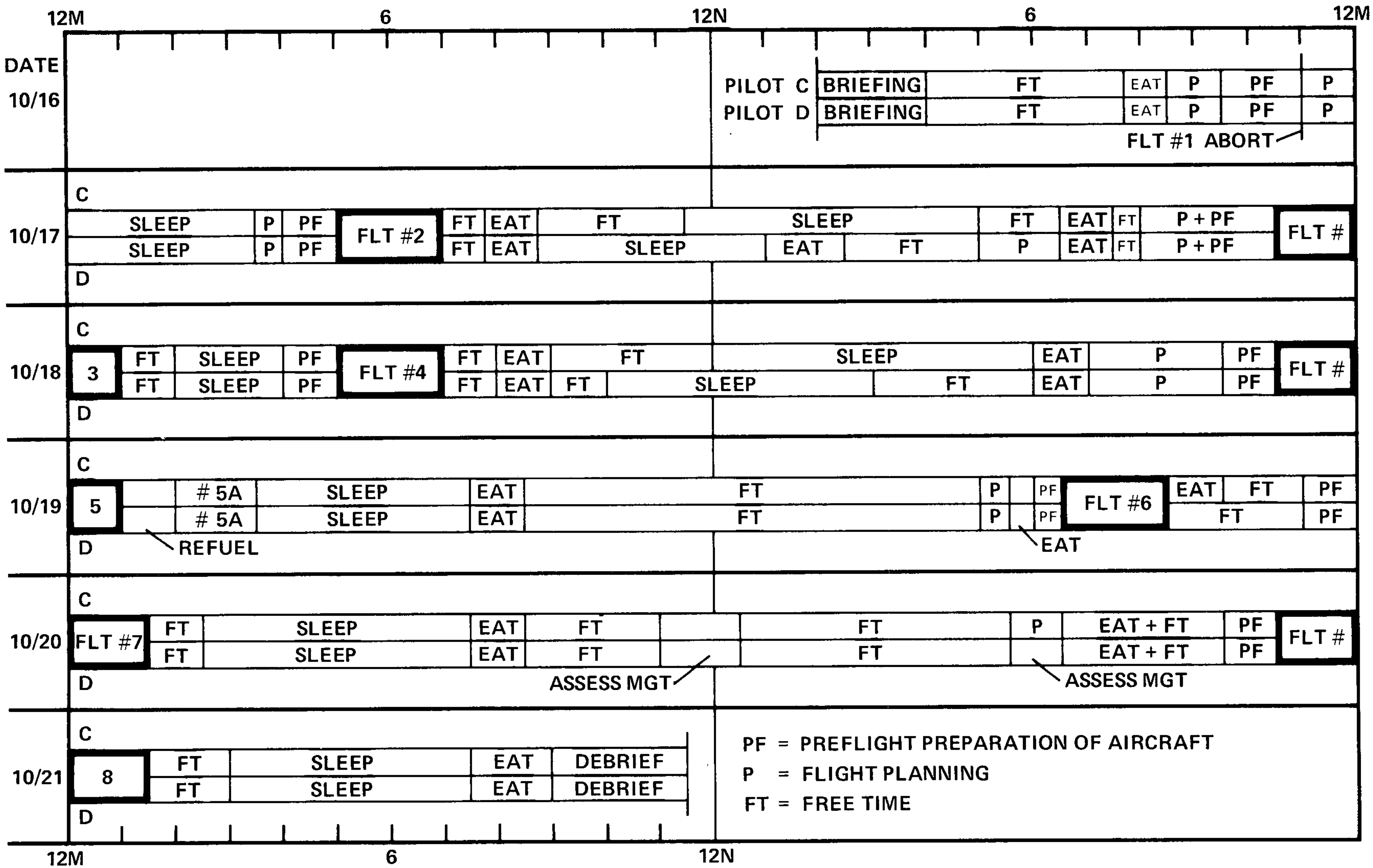

Figure 19.—Pilots' timelines.

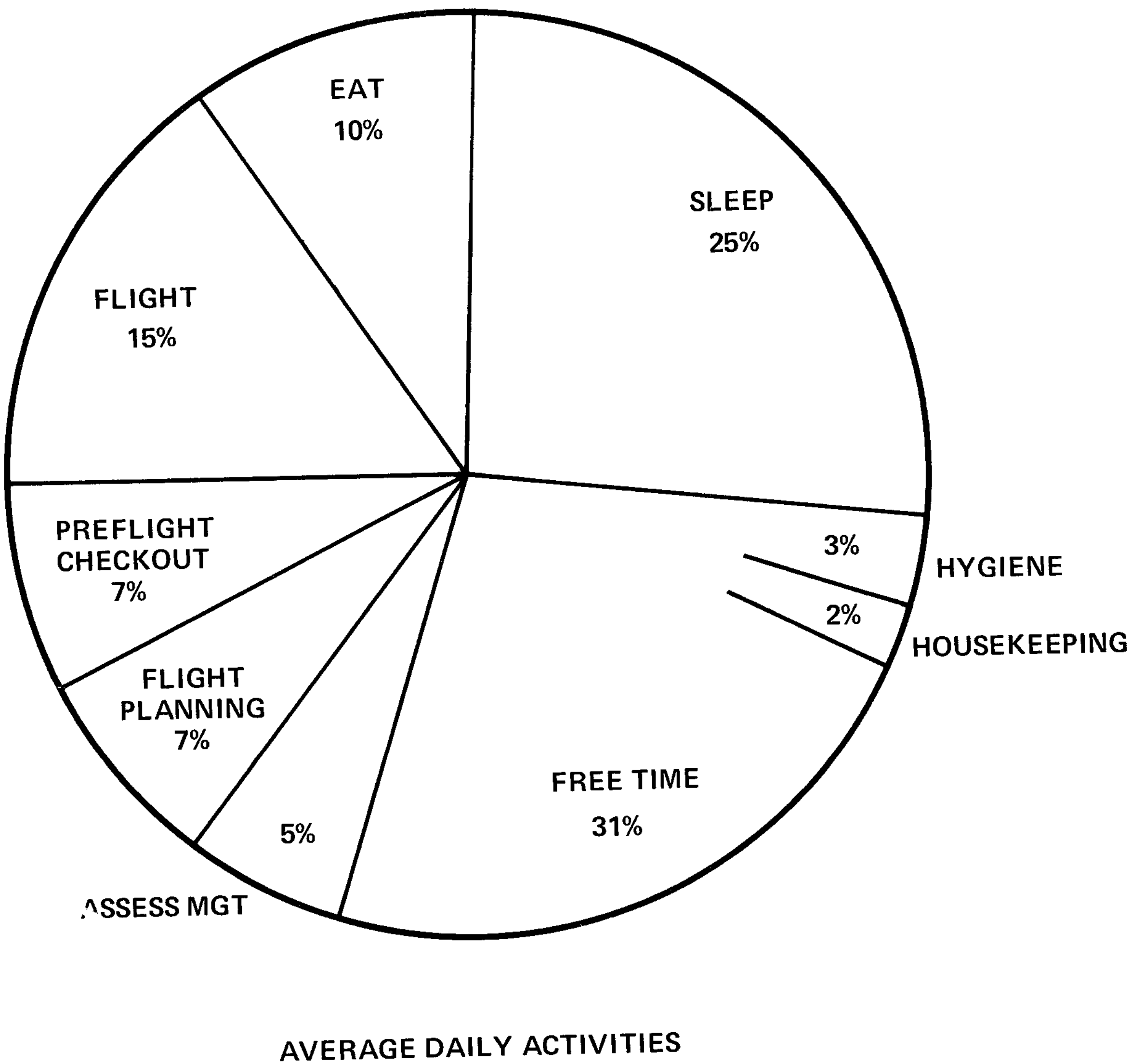

Figure 20.—Pilots' activity chart